Topographic and Geologic Survey Commission of Pennsylvania

Report No. 6

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TOPOGRAPHIC AND GEOLOGIC SURVEY OF PENNSYLVANIA

REPORT No. 6

GRAPHITE DEPOSITS OF PENNSYLVANIA

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LETTER OF TRANSMITTAL.

Hon. G. W. McNees, Chairman, and Members of the Topographic and Geologic Survey Commission:

Gentlemen: I have the honor to transmit herewith the manuscript and illustrations of a report on the Graphite Deposits of Pennsylvania, prepared by Dr. Benjamin L. Miller, and recommend its publication as report No. 6.

This is one of a series of reports on the lesser mineral deposits of the State, others being in press and in preparation. In the work of the Second Geological Snrvey little attention was given to these less important minerals, and their economic value at that time would hardly have justified the necessary investigations during the active years of that Survey. Since the time of the Second Survey many attempts have been made, with more or less success, to open, develop and work many of the deposits of these less important minerals and inquiries are being frequently made regarding them by parties within the State and elsewhere. It seems right therefore that the available data should be collected and placed in such shape as to properly answer these inquiries and furnish the information desired.

It is believed the accompanying report is one that will be appreciated by all interested in the subject of Graphite, both in Pennsylvania and elsewhere. The fact that so many attempts to work the deposits in this State have been failures, at least financially, is pointed out by Dr. Miller, and I think he makes the fact equally clear that these failures have been largely due to the "promoter," rather than the character of the deposits. It is of course true that in some cases the attempt has been made to work mines where the ore was of too low a grade, but it does not seem, from his investigations, that this has been the case generally, but the failure has rather been due to over capitalization and want of proper business management.

The failure of the operators in the graphite deposits in the past by no means shows that future operations will be failures, but all the information contained in the report shows that under proper conditions and the proper business management they should prove a success. The pointing out of the causes which has resulted in

the failures of the past is an important feature of any report which will be of real value to those interested in the subject treated, and with the information contained in this report there should not be a repetition of the past history of the graphite industry.

Very respectfully,

RICHARD R. HICE,

State Geologist.

April 18, 1912.

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INTRODUCTION.

Graphite is a form of carbon that is world-wide in its distribution but in workable quantities is restricted to a comparatively small number of places. Its uses are continually increasing and, at present, there are few manufacturing industries that do not have occasion to use it in some form. It is even said that there are few households that could not profitably employ graphite or praphite products to advantage.

For many years the United States has utilized about 25 per cent of the world's production of natural graphite and has produced from 4% to 20% of the whole. Seldom has the annual production equaled the imports of this mineral. Under these conditions it is not surprising that workable deposits of graphite have been sought in many states and that fraudulent promoters of graphite mining stock have found many willing victims.

Pennsylvania, with the exception of a few years, has long held second place in the list of graphite producing states and under judicious control should be able to materially increase its output. The industry has suffered greatly in the past through unscrupulous promoters and poor business management, and it may be many years before graphite mining in Pennsylvania can be placed on a stable basis. The deposits contain sufficient material, however, and the only question is that of profitably mining and separating the graphite from associated minerals. The lack of information concerning graphite deposits and graphite concentration has undoubtedly resulted in much useless expenditure of money and hindered the proper development of the industry. For these reasons it has seemed proper to prepare the following report.

The author has been materially assisted in collecting information by many persons to whom he is greatly indebted. Among these are the owners or officers of the various graphite companies now operating in the State, especially Dr. F. D. Chester and Messrs. Charles and George Pettinos. The officers of the Dixon Crucible Company have placed much valuable data in regard to the earlier development of the region at the disposal of the author. The geologic work of Dr. F. Bascom in the Piedmont Plateau of Pennsylvania, especially the manuscript geologic map of the Phoenixville quadrangle, has been of great assistance. Dr. E. S. Bastin of the U. S. Geological Survey and Dr. E. T. Wherry of Lehigh University have offered many valuable suggestions. Mr. C. G. Gilbert of the U. S. National

Museum and Mr. W. T. Lee of the U. S. Geological Survey have contributed articles on subjects with which they are especially familiar. Several former students have also aided in the field work among whom are Mr. Harvey Bassler, Mr. E. C. Smith, Mr. W. E. Henry and Mr. Sayre Welles.

PART 1

GENERAL DESCRIPTIONS

CHAPTER I.

HISTORY OF GRAPHITE.

Graphite is supposed to have been recognized by the ancient peoples as pieces are said to have been found in their graves and some of their pottery was colored with graphite. Its general use, however, seems to have come many centuries later and the earliest recorded mention discusses its use for drawing. It seems, however, that it was used long before in the manufacture of pots and crucibles as vessels composed in part of graphite have been found in prehistoric graves in Germany. Cennino di Rrea Cennini, an Italian painter of note who lived from 1360 to 1437, is the author of the oldest modern work on the technical processes of painting, entitled "Trattato della pittura" in which it is claimed that the earliest reference to graphite occurs. He describes a pencil composed of two parts of lead and one part of tin which he used in his work. The "lead" was probably graphite although this is not at all certain. Cennini may have used the term "lead" in its present sense as it is well known that ordinary lead will leave a mark on paper.

Agricola (1495-1550) describes refractory crucibles made of graphite and it seems that they were generally used by the old alchemists in their attempts to find some method for transforming the baser metals into gold.

In 1565 Conrad Gesner published his famous work on fossils and minerals entitled "De Rerum Fossilium, Lapidum et Gemmarum maxime, figuris & similitudinibus Liber," in which (pp. 104-105) the following passage appears: "Stylus inferius depictus, ad scribedum factus est, plumbi cuiusdam (factitj puto, quod aliquos Stimmi Anglicum vocare audio) genere, in mucronem dera si, in manubri um ligneum inserto."

The graphite used in the pencils described by Gesner seems to have come from the graphite mines of Borrowdale, England, which were opened about 1554 and furnished a fine grade of material for about three centuries. The graphite occurred in rather large masses and small pieces were carefully cut and placed in grooved pieces of wood in much the same way that lead pencils are now made.

For a long time graphite was confused with lead and two of its common names, "black lead" and "plumbago" (Latin, plumbum meaning lead) indicate its supposed relationship to lead. This was probably due to its metallic luster, which suggests a metal. The German chemist, Heinrich Pott, who lived between 1692 and 1777, proved that graphite was distinct from lead.

For many years after Pott's work had shown that graphite and lead were distinct, graphite and molybdenite were confused. Karl Wilhelm Scheele in 1779* determined its true chemical composition and proved it to be pure carbon.

The German mineralogist and geologist, A. G. Werner, in 1789† proposed the name "graphite" from the Greek word meaning "to write." Since that date the name has been used more than any other name although it is still called plumbago, black lead, kish, plombagine, potelot, aschblei, reissblei, fercarbure, crayon noir, carbo mineralis, etc. In this country the terms graphite, black lead, and plumbago are all in use and while they all refer to the same mineral it is interesting to know that there is some slight difference in their use. This is well stated by Malcolm McNaughton,** in the following passage.

"While these terms are synonymous, there have come to be certain peculiar applications in their uses—thus, we import "Plumbago" from the island of Ceylon, and "Black Lead" from Germany, Austria, and Italy, and, at the same time, we export "Graphite" from this country to all the other countries of the world. There are lead pencils, plumbago crucibles, and graphite lubricants; black lead stove polish, plumbago foundry facings, and graphite paint. This confusion of names may seem to be somewhat misleading at times, but there is considerable method in it."

The earliest uses of graphite were for the manufacture of crucibles in the fifteenth century and for pencils in the latter part of the sixteenth century. These two uses for many years were the only ones and there was a limited demand for the mineral. Within recent years many new uses have been found for this interesting mineral and consequently search has been made for it in all parts of the world with a considerable degree of success.

CHAPTER II.

PROPERTIES OF GRAPHITE.

Graphite is a black lustrous mineral crystallizing in the rhombohedral division of the hexagonal system according to most mineralogists although some observers have claimed that it belongs to the monoclinic system. The crystals are six-sided and tabular with striated faces. On account of its softness the faces are seldom distinct. When well crystallized in flakes it has a black to steel

*K. Vet. Akademieus Handlingar, Stockholm, 1779
†Bergmannisches Journal, 380, 1789.
**Stevens Institute Indicator, Jan. 1901, and Graphite, May, 1901.

gray metallic luster which is, however, practically absent in the fine amorphous material. In certain places it occurs in the form of large leaves or blades and less frequently in the form of fibers. The color is steel gray to black and the streak black. Its hardness is about 1.2 and its specific gravity from 2.09 to 2.23. It has a greasy feeling, a perfect basal cleavage, and is opaque. It is easily sectile and flexible, but not elastic. Its fusibility is unknown though probably above 3000° C. It is comustible at temperatures between 650° C. and 700° C. Chemically it consists of pure carbon, thus making it identical in chemical composition with charcoal and the diamond. Impurities are usually present in the natural graphite but these seem to occur between the thin laminae and to be purely accidental. Iron oxide, combined hydrogen, and clay are the most abundant impurities.

Graphite is a very stable mineral under atmospheric conditions and the soil formed from graphite-bearing rocks always contains flakes or smaller particles of the mineral.

The element carbon occurs in three forms: charcoal, diamond, and graphite. The charcoal consists of amorphous carbon while the others are crystalline. The three can be easily separated by chemical and physical tests. The specific gravity of charcoal is 1.57 to 1.88, of graphite 2.09 to 2.23 and of the diamond 3.5. Chemically the three can be separated by treating them with potassium chlorate and concentrated nitric acid in the proportion of 1 part of the substance to be tested, 3 parts of potassium chlorate, and sufficient acid to render the mass liquid. The mixture is then heated on a water bath for several days when it will be found that the diamond is unaffected, the graphite has been converted into golden yellow flakes of graphitic acid, and the amorphous carbon has been converted into a brown substance soluble in water. Many so-called graphites when treated in this way are proved to be charcoal, natural coke, or even coal or carbonaceous slate. Coal or carbonaceous slate can also be distinguished by the amount of volatile material present and all four by the low temperatures at which they will burn.

It is common to separate graphite into two classes designated by the two terms "amorphous" and "crystalline." The choice of terms is unfortunate for the reason that all graphite is crystalline carbon and is sharply separated from amorphous carbon as explained above. In practice we generally use the term "crystalline graphite" for those varieties that are coarsely crystallizezd and have a high luster, while "amorphous graphite" includes the varieties in which the particles are so small as to be indistinguishable to the naked eye and the substance has a dull or earthly appearance. Microscopic examination of some so-called amorphous graphites has shown them to contain very small crystals. The distinction between "amorphous"

and "crystalline" graphites would thus seem to be merely a difference in size of the graphite particles. "Amorphous" graphite and "crystalline" graphite are both true graphites and yield graphitic acid and, consequently, are distinct from amorphous carbon in the form of charcoal, coke, or coal although to the eye no distinctions may be possible between "amorphous" graphite and amorphous carbon.

On chemical grounds there does seem to be some justification for the terms "amorphous" and "crystalline" as applied to graphites. Both the Bohemian and Ceylon graphites are true graphites, the former "amorphous" and the latter "crystalline" but the graphitic acids of the two are dissimilar. The Bohemian graphite yields an amorphous yellow powder while the Ceylon graphitic acid occurs in the form of lamellar crystals. If the graphitic acid is decomposed by heat the material formed from the Bohemian graphite resembles lamp black and that formed from the Ceylon graphite is much lighter in color and seems to be in a less fine state of division. The conclusions to be drawn from these experiments are that there may be some differences in the molecular structure of the "amorphous" and "crystalline" graphites and consequently some fundamental reasons for their separation. More information is needed along these lines and until it is forthcoming we shall probably continue to use the inappropriate terms mentioned with the distinctions based on the physical appearances of the materoals.

Although graphite is opaque to ordinary light rays it is transparent to the X-rays, as is the diamond. Inclusions of various minerals invisible by ordinary light can thus be easily seen by the X-rays, appearing as dark particles. The high electrical conductivity of graphite renders it desirable for electrical work and much of it is thus utilized. It is also a good conductor of heat and consequently feels cold to the touch.

Attempts have been made to classify different varieties of graphite by their action when treated with chemicals. Certain varieties were observed to swell up and assume worm-like coils when heated with boiling nitric acid and afterwards ignited, while others were unaffected by such treatment. The former have been called "graphite" and the latter "graphitite," the assumption being an inherent difference in the form of carbon in the two cases. The peculiar behavior of the former is believed to be due to inclusions of liquid between the lamellae, and that the two forms are not essentially unlike. These distinctions are seldom made now. The term "graphitoid" has also been employed for an impure variety of graphite which contains nitrogen and water, and which burns in the Bunsen flame.

Graphite is often confused with molybdenite which has certain physical properties that are similar. The streak of the latter on porcelain is slightly greenish and the luster somewhat more silvery

than that of graphite, but at times these distinctions are not especially noticeable. The specific gravity of molybdenite is about twice that of graphite. The fact that molybdenite contains sulphur renders its determination easy by means of the blow-pipe. Graphite may also be confused with certain varieties of biotite because of the black color, high luster, and perfect basal cleavage but the greater hardness and the elasticity of the biotite flakes render the separation an easy matter.

"Fusion with alkaline carbonates produces carbon monoxide (CO), which puffs through the molten material and ignites as fast as formed, the graphite being consumed in reducing the carbonate. Pure molten caustic-alkali, at a low red heat, does not attack graphite appreciably but separates it from its mineral constituents and leaves the graphite in a free and purified condition. Thus pure graphite may be obtained and its percentage determined by direct weight. Pure graphite is not altered by heating in a stream of dry chlorine gas; nor is it affected by hydrofluoric or hydrochloric acids.

"Graphite of the best quality, such as the Ticonderoga flake, or powdered Ceylon plumbago, is but slowly attacked by molten potassium nitrate at a low red heat. Certain metallic oxides, upon the surface of molten metal or alloys, at very high temperatures, have a tendency to oxidize or 'burn out' graphite; and the same is true with respect to strongly oxidizing slags which have high melting points. Therefore, plumbago pots for melting steel rarely average more than 6 or 7 heats, while pots for melting brass may outlast 18 or 20 heats.

"Graphite may be completely oxidized by a mixture of chromic and sulphuric acids. It may also be converted to carbon dioxide in a combustion furnace, but a far simpler method is to heat the graphite directly in a platinum dish over a Bunsen flame while a gentle stream of oxygen plays on the surface of the material.

"In the assay of graphite, allowance should always be made for moisture, combustible organic matter, and sulphur. Sulphur is an undesirable element in plumbago pots used for melting silver or high-grade alloys. In fact, sulphur in the form of pyrites should always be eliminated as far as possible in the milling process. It is not unusual to find red spots on kiln-burnt pots, due to the iron roasted out of the pyrite. Small plumbago crucibles, when subjected to a clean blast in a gas furnace, at a yellow heat, often exhibit fused pittings due to fluxing of iron oxide with mineral matter; and this is generally the case when the plumbago is known to contain pyrites even in very small amounts."*

*F. S. Hyde: Eng. and Min. Jour., Vol. 85, p. 256, 1908.

CHAPTER III.

OCCURRENCE OF GRAPHITE.

Graphite is one of the few minerals that occurs in Nature under widely different conditions and is also produced artificially in many ways. It is found in igneous, sedimentary, and metamorphic rocks in varying amounts.

The statement is frequently made that graphite does not occur in unchanged sediments but this is erroneous. Emerson* has described an unmetamorphosed Triassic sandstone in Massachusetts that contains "scales of graphite in considerable number." Obviously graphite occurring in such rocks owes its origin to nearby metamorphic or igneous rocks in which the graphite was formed. Graphite being little affected by weathering agents would not be affected chemically when the containing minerals were decomposed and the rock disintegrated. On account of its softness, however, the graphite flakes are usually ground into such fine particles during transportation that they escape detection in the sediments, especially when mixed with large amounts of other minerals. Perhaps, in places, the black coloring matter of sedimentary rocks, usually supposed to be amorphous carbonaceous matter is, in reality graphite. Since graphite owes its origin to great heat, the graphite occurring in unchanged sedimentary rocks must owe its origin to the disintegration of graphitic rocks of igneous or metamorphic character so that we do not expect to find graphite deposits of any economic importance in unmetamorphosed sedimentary rocks even though later investtigations may show its rather wide-spread presence in such materials.

There has been much discussion concerning the presence of graphite in igneous rocks as a primary constituent of the magmas and many geologists have assumed that the presence of graphite in metamorphic rocks furnished positive proof of the sedimentary origin of such rocks. Such geologists attribute the source of the carbon solely to organisms that were entombed in the sedimentary rocks. Others have held that the presence of graphite in igneous rocks is purely accidental and that the carbon has been picked up from surrounding rocks. While this may account for some graphite found in igneous rocks it surely does not account for all occurrences in these and we

*Monograph No. XXIX, U. S. Geol. Surv., p. 365.

must conclude that graphite is an igneous as well as a metamorphic mineral. This question is discussed more fully in a later chapter under the head of "Origin of Graphite."

In igneous rocks graphite occurs in meteorites, in nepheline syenite, in basalt, and pegmatites. It is usually segregated in such rocks, the graphite occurring in comparatively large irregular masses of great purity. This is especially true of the graphite of the pegmatites.

In the metamorphic rocks graphite occurs most abundantly, and with few exceptions all the workable graphite deposits of the world occur in such rocks. Gneisses, schists, quartzites, marbles, and slates contain graphite in various places and in variable amounts. Besides we find, in certain places, beds or veins of practically pure graphite which have probably been formed from beds of coal or from veins of asphaltic materials that have undergone metamorphism.

In the gneisses, schists, quartzites, marbles, and slates, the graphite occurs disseminated throughout the rocks either in the crystalline flake form or as amorphous graphite. In most cases the flakes are oriented so that the flat faces are parallel, particularly in the schists, quartzites and slates. In the case of the marbles and also in some of the gneisses the graphite flakes show no orderly arrangement.

The graphite of the slates is almost invariably amorphous, that of the marbles almost always crystalline, while that of the other kinds of rocks may be either crystalline or amorphous.

Where beds of coal have been metamorphosed to graphite by dynamic action or by contact with igneous intrusions the graphite preserves many of the structural characters of the original material. Such graphite is amorphous and is in most cases very pure.

Veins of graphite occur in fissures and are of various widths. In some places veins six feet in width have been reported but seldom do they exceed a foot in width and most of them are much smaller. The purest graphite usually comes from veins. Much of the Ceylon graphite, which is found in veins, contains 99+% carbon.

The vein graphite is crystalline and is fibrous, foliated, or bladed but does not occur in flakes.

There are no minerals that can be regarded as invariably associated with graphite. Quartz is undoubtedly the most common one, yet almost all the rock-forming minerals, and especially the minerals of the metamorphic rocks, are found in association with graphite in one locality or another. Mica and chlorite are all too common and render some deposits valueless because of the difficulty experienced in separating them from the graphite. Pyrite and pyrrhotite are abundant in many localities and due to their presence the weathered outcrop of the graphite bed is apt to appear as a band of reddish-yellow

soils. In Pennsylvania limonite mines have been worked in several places in the upper weathered portions of the graphite beds where the iron, in the form of limonite, has been concentrated as the pyrrhotite-graphite rock decomposed. Several iron mines of this kind, formerly worked, are located near Chester Springs and Kimberton.

Near Seisholtzville, Berks county, graphite is found associated with magnetite in a basic rock, while in Ovifak, Greenland, it is found in basalt in association with native iron.

Because of the interest attached to the presence of graphite in meteorites, Mr. C. G. Gilbert, Assistant Curator in the U. S. National Museum, has been asked to prepare a short discussion on this subject which is here incorporated. Mr. Gilbert has made a special study of meteorites for many years and is consequently qualified to discuss this topic.

"Apart from gradational types, meteorites, as a whole, admit of a ready, even if arbitrary, division into groups essentially metallic for the one part, and essentially stony for the other. In each of these groups, uncombined carbon occurs, though in quite different relationships. As observable in the former, it has quite obviously been a segregation product from the nickel-iron alloy during a protracted process of solidification; in the other, whatever its relationships in the original, its present one is exactly definable merely as a rare accessory constituent. In the one, though in varying proportions, it may safely be regarded as an ever present ingredient; in the other it is so rarely present as to be the most striking single characteristic of the limited group in which it has been found.

"Carbon has been found in every meteoric iron in which it has been sought. Its commonest mode of occurrence in segregations is such that analyses cannot be taken as showing in definite figures the actual percentages present, but limits of 0.01% and 1.5% would approximately bound its range. With sulphur and phosphorus it would seem to have been an ever present impurity in the parent nickel-iron magmas from which iron meteorites have solidified. To a very limited degree the carbon, like its associates, has entered into definite combination with the metals, but its common occurrence is as free carbon, in which crystalline forms are almost negligibly rare. Accordingly the three observably noteworthy occurrences of carbon in the metallic division of meteorites is:—

(1) In combination as the mineral cohenite to which the formula $(Fe,Ni,Co)_3C$ has been assigned.*

(2) Crystallized as free carbon in the minerals cliftonite and diamond.

(3) Massive nodular aggregates and disseminated particles of graphitic carbon.

*E. Weinschenk: Über einige Bestandtheile des Meteoreisens von Magura, Arva, Ungarn. Annalen des k. k. Naturhistorischen Hofmuseums, 1889, IV, 94-97.

"Of cohenite little further need be said in this connection. It is a strongly magnetic, metallic mineral, tin-white on fresh break, but tarnishing readily to a bronze-yellow. It has a hardness of 5.5 to 6, a specific gravity of 7.23, and crystallizes in the isometric system. Its occurrence in meteoric iron has been positively recorded in a few instances only, but systematic search would presumably result in identifying it as a common though minor constituent. Cohenite has been found in the terrestrial native iron from Niakornak, in Greenland,* and a carbide of iron similar at least to it may be obtained from cast iron which has been cooled down slowly from a temperature of 700° C.

"A cubic form of crystalline carbon was observed in 1887 by Fletcher in the meteoric iron from Youndegin.† While admitting the possibility of its being merely a pseudomorph, he was disposed to discredit such an origin, and christened his find cliftonite. In the light of subsequent observations disclosing the actual presence of diamond, Brezina suggested the possibility of cliftonite being a pseudomorph after diamond. If true, it would be an interesting occurrence, since cliftonite has been found by Huntingdon to constitute 0.15% of the Cosby Creek meteorite, one of the crystals an octahedron measuring a centimeter in axial dimension. The mineral has a hardness of 2.5, a specific gravity of 2.12, and in its crystallization affords faces of the octahedron, dodecahedron, and tetrahexahedron. Cliftonite occurs certainly in six meteoric irons associated with dense nodular graphitic carbon, and has no known terrestrial counterpart.

"While suggested in several earlier instances as the possible nature of certain exceedingly hard grains too small to afford definite characterization, diamonds were first positively identified as a constituent in meteoric iron in 1891, in observations by Foote,** supported by König. Repeated investigations by Kunz, Huntingdon, and others, have substantiated these results beyond question. They have been found in no iron other than the Canon Diablo in which they occur as minute grains disseminated through the great nodular segregations of graphitic carbon which characteriz ezthat iron. They range from black through more or less transparent brown to the clear gem variety, but are far and away too minute to be of more than purely scientific value. Results from investigations of the various terrestrial iron masses stimulated by the Canon Diablo findings have in every instance been negative.

"The several occurences of carbon in meteoric iron treated thus far are more or less purely incidental as compared with the graphitic form which the element characteristically affects. As such it con-

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*Forehammer: Om meteorjarnet fra Niakornak. Oversigt over det Kongelige Danske Videnskabernes Selskabs Fordhandlinger og dets Medlemmers Arbeider. 1854. pp. 3-4.

†L. Fletcher: Nature, XXXVI, 304-5. Mineralogical Magazine, VII. 124-30.

**A. E. Foote: A new locality for meteoric iron, with a preliminary notice of the discovery of diamonds in the iron. American Journal of Science. (3). XLII, 1891, 414-416.

stitutes a dissemination throughout the metal, and segregated nodules, either pure or associated, often concentrically, with the sulphide of iron, troilite, and the nickel-iron phosphide, schreibersite. Such nodules have been observed ranging over a hundred grams in weight and consisting of carbon 99% pure. Certain irons such as those belonging to the Toluca and Canon Diablo finds, in section will not infrequently offer six or eight graphite nodules ranging up to an inch or even more in diameter, and, deeply etched with hydrochloric acid, the polished surface will be dimmed by a residual graphitic film. Even the pure carbon segregations are mere compact dense accumulations. Rarely they evince a somewhat scaly tendency, but graphite in truly crystalline form has never been observed in any meteorite, metallic or stony.

"In the essentially stony division of meteorites, uncombined carbon has been isolated in sixteen members, and ranging as high as 4.66% of the whole.* None of the preferences exhibited in terrestrial occurrences are manifest, and apparently the presence of carbon is the only general characteristic of the group in which it occurs not shared equally with other stony meteorites. It occurs crystalline as diamond, and amorphous as a finely disseminated dust cloring the stone black and remaining as an insoluble residue when the mass of the stone has been brought into solution. Unlike the free carbon of the metallic division which characteristically assumes the massive graphite form, however, that of the stony meteorites, while its occurrence as graphite has been recorded, adheres characteristically to the truly amorphous state.

"To Jerofejeff and Latshinac,† working in collaboration on the stone from Nowo Urei, Russia, belongs the credit of having first disclosed the presence of diamonds as a constituent mineral in meteorites, and subsequently one other stone, that from Carcote, in Chile, has been added by Sandberger.** In Nowo Urei it was found to constitute about 1.0% of the mass. As in the case of Canon Diablo, however, the individual crystal gains are of almost purely microscopic dimensions. Nowo Urei contains considerable amorphous carbon in addition, a fact which is not equally true of Carcote.

"As has been intimated, a prospector in the field of meteorites would apparently have very little indeed in the way of criteria as to associations best suited to the presence of free carbon. Perhaps the most strikingly interesting one fact to be gleaned is the apparent commonness of its occurrence, in the amorphous form at least, in a rock of such basic composition as constitutes meteorites, whereas

*Reported for the Mighei meteorite by S. Meunier. Confirmatory analyses would seem called for, however, before such a remarkably high percentage can be accepted unreservedly. For the present, 2.5% or possibly 3.00% would be a safer maximum.

†M. Jerofejeff and P. Latschinoff. Der Meteoriten von Nowo Urei. Verhandlungen der russischen kaiserlichen mineralogischen Gessellschaft, 1888 (2) XXIV, 272-76, 286-87, 290-92.

**F. V. Sandberger: Ein neuer Meteorit aus Chile. Neues Jahrbuch fur Mineralogie, Geologie und Palaeontologie, Stuttgart, 1889, II, 180.

the characteristic of graphite is in the acid rock. The only apparent exception to this rule is the native iron-bearing basalt of Greenland which is known to carry graphitic carbon. The inference suggests itself at once that free carbon associates itself with native iron in that original source, whatever its nature, from which solidified rock has been derived. Facts do not wholly bear out this inference, however, for meteoric rocks containing metallic iron only as an accessory may be far higher in carbon than those containing greater amounts of iron, or consisting almost purely of the metal, and there is no apparent connection whatever between the percentages of the two present. Even granting the correctness of this inference, moreover, it in nowise explains, but rather augments the apparent anomaly of having free carbon a characteristic of acid, granitic rock on the one hand, and of ultrabasic rock on the other. In the light of present knowledge, free carbon offers the contradiction of presenting itself as crystalline graphite only in the highly acid granitic rock, and amorphous purely in ultrabasic rock."

CHAPTER IV.

ORIGIN OF GRAPHITE.

Geologists have long discussed the origin of graphite and perhaps more theories have been proposed to account for this mineral than for any other economic product. Even at the present time there is considerable difference of opinion and there is need of additional experimental work before all questions concerning the origin of this widely distributed mineral are conclusively answered. It would be useless to attempt a full account of all the theories that have been proposed and consequently only the more plausible explanations are considered.

For many years the discussions of the origin of graphite centered about the question of its origin from inorganic matter. Certain deposits were generally recognized as being due to the metamorphism of organisms contained in sedimentary rocks and many geologists maintained that all graphite had a similar origin and that the presence of graphite in any rock was positive proof of its original sedimentary character. Even at the present time, in certain places, metamorphic rocks containing graphite are regarded as altered sediments with no proof or evidence in addition to the presence of the graphite.

It is now proved beyond much question that graphite is of organic origin in certain places and of inorganic origin in others. The presence of graphite in rocks of undobuted igneous origin was not con-

sidered sufficient proof by some that the carbon was a primary constituent of the original magma as it was thought that the carbon might have been incorporated in the igneous mass as it passed through carbonaceous sediments on its way to the surface. The discovery of graphite in meteorites, however, in which there is complete lack of evidence of any organic material, seems to have convinced most geologists that graphite occurs in Nature as a product of inorganic origin as well as of organic origin. With this question definitely settled there still remains much discussion concerning the origin of particular deposits. Some persons are convinced that a considerable portion of the graphite deposits of the world have resulted from inorganic compounds while others take the position that graphite with such an origin is very rare and represented by but few occurrences.

GRAPHITE OF INORGANIC ORIGIN CONTAINED IN TERRESTRIAL IGNEOUS ROCKS.

Admitting that graphite has an inorganic origin in certain places the problem of the form in which the carbon originally existed demands explanation. Winchell has recently discussed this subject somewhat elaborately in two articles* which are based upon the physical chemical work of Coquillon,† Boudonard‡ and Weigert.§ His conclusions are that the carbon of graphite probably existed in the igneous magma in the form of CO or CO_2.

Some have believed that the graphite of igneous rocks existed in the magma as flakes surrounded by the liquid minerals or dissolved by them. That the graphite did not solidify before the other minerals is proved by its relation to other minerals of the rock; in some rocks it surrounds certain minerals, in others it is intergrown with them, and in most igneous rocks it is rather evenly distributed throughout the mass. All these facts indicate that the graphite crystallized either at the same time or even later than certain of the associated minerals.

Because of the presence of hydrocarbons in igneous rocks some have believed that they have given rise to graphite. This seems improbable because the hydrocarbons in the presence of highly heated water vapor, which is almost invariably present in magmas, would tend to decompose to form CO or CO_2 and hydrogen.

The decomposition of metallic carbides supposedly present in the magmas is thought by some to have been the source of graphite but this seems unlikely since most of the metallic carbides are unstable at magmatic temperatures and the metals of those that are stable at such temperatures are absent from rocks that contain graphite.

*Econ. Geol., Vol. VI, pp. 218-230, 1911. Bull. No. 470, U. S. Geol. Survey, pp. 530-531, 1911
†Compl. Rendus Vol. 86, p. 1197, 1878.
‡Annales Chim. Phys., Vol. 24, p. 5, 1901.
§Abegg's Handb. Anorg. Chem., Vol. III, Pt. 2, p. 196, 1909.

The compounds CO and CO_2, which are known to be liberated during the eruption of volcanoes, seem to furnish the most likely source for the carbon of the graphite found in the igneous rocks. It has been experimentally shown that when a solution of these gases and hydrogen cool, the hydrogen unites with the oxygen to form water and the carbon is precipitated. It seems therefore highly probable that when magmas containing CO and CO^2 cool, graphite forms, and this accounts for the graphite of igneous origin. The temperature at which it forms is below 650° C., consequently we may expect to find the graphite interlocking with associated minerals that solidify at that temperatue or even surrounding minerals whose solidification temperature is higher.

GRAPHITE OF ORGANIC ORIGIN.

No one has ever questioned the origin of graphite from organisms, plants or animals, and yet several points connected with the transformation of amorphous carbonaceous materials into crystalline graphite are in dispute. The agencies responsible for the transformation seem to be unquestionably heat and pressure, probably always accompanied by the action of heated aqueous vapors. Bastin has recently shown* that graphite has probably crystallized at a temperature not exceeding 575°C., a temperature much lower than was formerly supposed necessary. The heat in some cases was plainly that produced by the intrusion of igneous matter into a bed of carbonaceous sediments, which may be termed heat of contact metamorphism, while in other cases the heat has been produced by great compression of the rocks due to adjustments of the earth's segments, and termed dynamic or regional metamorphism.

The best examples of graphite formed by contact metamorphism are the deposits of Sonora, Mexico, and Raton, New Mexico. In both places coal beds have been intruded by dikes of igneous rocks that have converted the coal into a high grade amorphous graphite. The Sonora product is especially pure and furnishes the greater portion of pencil graphite consumed in this country. In other places carbonaceous slates have had their carbon content converted into graphite in the vicinity of the igneous intrusions.

The most important organic graphite deposits of the world, with few exceptions, owe their origin to dynamic or regional metamorphism of sedimentary rocks, whether sandstones, limestones, or shales, in which carbonaceous material was originally present. All of the graphite of Pennsylvania with the possible exception of that contained in the pegmatites and the occasional small veins has had such an origin. It is not advisable here to discuss the causes for the earth adjustments that resulted in the squeezing and consequent meta-

*Econ. Geol., Vol. V, pp. 134-157, 1910.

morphism of the rocks of the Piedmont Plateau but it is sufficient to note that there is abundant evidence of such disturbance in this State. The graphite was undoubtedly formed at this time from organic carbonaceous matter and the enclosing limestones were converted into coarsely crystalline marbles, the shales into gneisses, and the sandstones into quartzites.

The graphite is possibly due in part to the carbonaceous portions of animals but mainly to the remains of plants. The real source of the carbon cannot be determined in those rocks where all traces of organic structure is now obliterated, as is true of the metamorphic rocks that now contain graphite, but probably the graphite derived from animals would present no distinguishing characteristics from that formed from plants if we were able to determine this point.

David White* suggests algae as the probable source of the graphite of the pre-Cambrian metamorphic rocks of Pennsylvania, New York and several other states and this statement, based on his paleo-botanical researches, seems wholly justified. So far as we have any evidence on the subject, the indications are that the only plants then existing were marine forms of a low order such as the algae.

The process by which the remains of the plants, composed of carbon, hydrogen, and oxygen, were changed into graphite, was probably analogous to the formation of graphite from the gases of igneous rocks described on a preceding page. Certainly each flake of graphite now occurring in the limestones or other rocks and arranged, in places, at all angles does not represent the remains of a single plant or cluster of plants converted into graphite *in situ*. The hexagonal outline of many of the graphite flakes also shows a transfer and an orderly arrangement of the carbon molecules during the metamorphism.

The carbon of the plants was converted into the hydrocarbon compounds mainly, but probably into CO or CO_2 in part, by the action of the heat and pressure. These gases were then free to move within the semi-plastic mass and subsequently decomposing gave rise to the graphite. The graphite particles were segregated during the process and under certain conditions were arranged in regular order to form the hexagonal crystals.

In some places carbon compounds in the gaseous condition may have moved into fissures where they were decomposed to form viens of graphite. Thus graphite veins may have either an organic or an inorganic origin. The close connection of the graphite veins and the pegmatites of Pennsylvania to the graphitic gneisses and limestones suggests for them an organic origin but the evidence is not conclusive.

*Econ. Geol., Vol. III, p. 298, 1908.

CHAPTER V.

USES OF GRAPHITE.

The uses of graphite are many and are continually increasing. Few people are aware of the great variety of purposes for which it is suited by its peculiar physical and chemical properties.

Its value depends upon its resistance to the action of heat and corrosive agents, its high conductivity of heat and electricity, the thin character of the flakes, their flexibility and softness enabling them to be spread out under pressure to form a smooth and almost frictionless surface or a black glossy coating, its opaque black color and streak, the ease with which the latter may be obtained and its permanent character, and the absence of occluded gases such as are usually present in amorphous carbon.

The average person doubtless believes its principal use is in the manufacture of lead pencils, while that is, at present, one of the minor uses. Although it is impossible to be specific in stating the proportion of the world's supply used for various purposes it seems that the following table approximately represents the proportions in which it is consumed in various manufactured products.

Crucibles,	55%
Stove polish,	15%
Foundry facings,	10%
Lead pencils,	5%
Paint,	5%
Lubricants,	5%
All other purposes,	5%

CRUCIBLES.

Due to its highly refractory character and low ash content graphite is eminently suited for the manufacture of crucibles and other articles that must be exposed to high temperatures and there seems to be little doubt but that it there found its earliest use. It is believed that graphite crucibles were manufactured near Passau in Bavaria in the earliest part of the fifteenth century and were used by the alchemists of the Middle Ages.

There is a difference of opinion among manufacturers regarding the best variety of graphite for crucibles. Some claim that Ceylon graphite alone is suitable for the best articles while others assert that flake graphite such as is produced in Pennsylvania is equally good, if not better. Those who favor the Ceylon product claim that it owes

its desirable character to the fact that it breaks into foliated masses or thick rods rather than in thin flakes and when crushed is more even-grained. Also its greater purity is in its favor, Ceylon graphite often running over 98% carbon while flake graphite of that purity can seldom be obtained. Those who contend that the flake graphite is preferable base their claims upon the greater toughness of the flakes and greater binding properties. Regardless of the relative merits of the two grades of materials both are used with satisfactory results. The bulk of the Ceylon graphite imported into this country is used in the manufacture of crucibles and has been imported for that purpose ever since 1829 when Joseph Dixon brought his first shipment of the Ceylon product to his crucible manufacturing plant then located at Salem, Mass.

In the manufacture of crucibles the graphite owes its value to the fact that it does not fuse at the temperature at which most metals and alloys melt and also is a good conductor of heat. By experiment it has been shown that due to the ease with which the graphite conducts the heat from without the crucible to the metal within much less fuel is consumed when graphite crucibles are used than when clay crucibles are employed. Time is also gained because the metal melts more quickly. Further, graphite crucibles can withstand sudden changes in temperature much better than clay crucibles. Downs* says: "I have heated a small crucible to about 1400°C., and then suddenly plunged it into water, returned it to the fire and repeated it again and again until it had been shocked 20 times. If rung by striking it with the finger or a small bar, the crucible showed no change in the note of its ring until after the twelfth shock; by the time the twentieth was reached the note was nearly gone. In actual service, where the shock to which the crucible is subjected is not as sudden or severe as that just stated, a crucible has been known to stand from 80 to over 100 charges, though the average life is from 20 to 60 charges when used in melting copper alloys or equivalent metals."

"A list of the various kinds of work in which graphite crucibles are used as the melting pot includes malleable castings, small iron castings, crucible cast steel, all kinds of copper alloys (brass, etc.) spelter castings, file temperings, gold and silver melting and refining. Also oblong, square and round shapes are used in liquid brazing, and as calcining trays or boxes for materials requiring careful, even heating without exposure, such as pencil leads, incandescent light carbons, etc. One of the most interesting uses of the graphite crucible is that of a retort. The distillation of metals certainly requires special retorts if the metallic fumes are to be condensed and used. The best instance of the service is shown in the zinc distillation process now

*Iron Age, Vol. LXV, May 24, 1900, p. 5.

in use in all the silver refining works. Here the graphite retorts or bottles, are used in tilting furnaces and have a holding capacity of 1500 pounds."*

In the wide variety of uses of graphite crucibles naturally different ingredients are used and in varying proportions. The graphite itself possesses practically no binding strength and this property must come from substances mixed with the graphite. Clay, sand, and kaolin are the materials usually employed. The clay must be a high grade fire clay, with great plasticity, high percentage of combined moisture and extremely low in iron oxide, the alkalies, and alkali earths. Few clays produced in this country meet these requirements and hence most of the clay used in the manufacture of crucibles in the United States comes from Europe.

The sand used must be composed of practically pure silica (SiO_2), while the kaolin which is used for the purpose of influencing the fusibility of the mass must also be free from impurities, especially iron oxide.

Although the proportions of the materials vary according to the different purposes for which the crucibles are to be used it is said that most of them consist of about 3 parts of graphite, 2 parts of clay, 1 part of sand, and smaller amounts of kaolin. Analyses of crucibles used by crucible steel manufacturers show the following results:—

Graphite	44% to 46%
Silica	34% to 38%
Alumina	15% to 17%
Iron oxide	1% to 3%

In the manufacture of the crucibles especial attention is given to the mixing of the ingredients. This is done in machines containing revolving arms that pass through the mass in different directions and the process is continued for a considerable length of time to insure a uniform distribution of the materials. A large amount of water is added to facilitate the process.

The crucibles are moulded as is ordinary pottery by machines or by hand into various shapes and sizes according to demand. Usually the crucibles have the shape of an egg flattened at the broad end and truncated at the narrow end. Some are several feet in height and are made to hold over 1000 pounds of molten metal. The base is considerably thicker than the sides.

After being moulded the crucibles are carefully and slowly dried for a period of several weeks. Unless particular care is given to them during this stage many of them crack owing to the shrinkage of the clay. When thoroughly dry they are placed in kilns and burned in the same manner that pottery or brick are calcined. Not infre-

*Op. cit., p. 5.

quently in the burning process some of the crucibles turn white on account of the graphite being burned out of the outer portions but it is only a thin film that loses the graphite and the value of the crucibles is not affected in any way.

OTHER REFRACTORY USES.

Closely allied to the manufacture of crucibles is the making of muffles, phosphorizers, stoppers and nozzles, used in open hearth stove works, brazing boxes, stirrers, dipping cups, skimmers, etc.

STOVE POLISH.

Stove polish is one of the common articles in which graphite is used in large amounts. For this purpose various grades of material are used but principally the amorphous variety from Bavaria. If the flake graphite is used a higher luster is obtained which has a decidedly steel gray color. This is owing to the flattening out of the flakes on the metal surface when rubbed by the brush and to the fact that light reflected from the surface of the flakes produces a higher luster than when the amorphous graphite is used. Not infrequently both amorphous and crystalline flake graphite are mixed together to produce the desired results. With the amorphous graphite alone it is difficult to obtain a lustrous polish while the crystalline flakes alone produce too light a color, but the combination of the two varieties will yield a black polished surface with the expenditure of little labor. The polish obtained with the flake graphite alone or with the mixture of the two also lasts longer than the polish obtained with amorphous graphite alone.

In the manufacture of stove polish the process is simply one of throughly mixing the finely-ground graphite with a certain amount of clay and compressing it in the form of cakes just as bricks are moulded.

Graphite, especially the amorphous variety, is also used sparingly in the manufacture of shoe polish.

FOUNDRY FACINGS.

"The practice of facing moulds in which castings are to be made with some carbonaceous material, is general. The material used is usually anthracite, charcoal, or graphite. The reason for its use is for the purpose of preventing the adhesion of the iron to the sand of which the mould is made. The principle of its use for this purpose is as follows: The air contained in the mould, and which is carried in by the stream of molten metal, furnishes oxygen for the combustion of the carbon material of which the facing is composed, so that a condition obtains analogous to that of the spheroidal condition of a drop of water on a hot surface; thus the iron is effectually

prevented from coming in actual contact with the sand, so that when the casting is removed, it will be found to be covered with a thin crust which will easily peel off, leaving the iron smooth and clean. In order to secure perfect results, certain conditions must prevail.

"First, the facing must adhere perfectly to the mould surfaces. The hot metal coming in contact with the sand, dries it out, and if the facing has not been properly compounded, it will be washed away in front of the advancing metal—so it is necessary to have a certain percentage of clayey material mixed with the facing to prevent its "running" before the metal.

"Second, it must be slowly combustible. If the facing burns quickly, trouble is likely to ensue from two causes:

(a) too great volume of gas to be readily vented, this causing 'blows' and 'cold shuts;' the latter term being applied to those cases where the iron has not filled the mould.

(b) where combustion is too rapid, it is not likely to endure during the entire time that the metal is in the fluid condition, so that while at first the spheroidal condition exists, it ceases before the metal is solidified—thus giving every opportunity for adhesion.

"Castings which have been made in connection with the use of a facing well suited to the particular case are superior because of a finer surface texture, of ease of cleaning and less tendency to dull the cutting edges of machine tools. Plumbago is the one material which combines in a greater degree than any of the others, the requisites which are necessary to a good facing. It contains no volatile matter whatever, it burns evenly and slowly, so that a less quantity may be used. It has in addition another quality, that of ability to being sleeked or polished, giving the very smoothest surface to the mould."*

LEAD PENCILS.

The second use of graphite so far as we have any records seems to have been in the manufacture of lead pencils and dates from the middle of the sixteenth century. The famous Borrowdale mine near Keswick in Cumberland, England, opened in 1554, furnished the first material so used. It was first called "black cawke" or "wad" and was used for marking sheep. Later strips were cut from the larger masses and these were placed between two pieces of grooved wood producing pencils not unlike those in common use today, although they were probably larger in size and contained thicker pieces of graphite. The graphite of the Borrowdale mine was similar to the Ceylon graphite, occurring in veins, and yielded material well suited for the purpose. For nearly three centuries this mine was worked and for the greater portion of that time fur-

*Graphite, Vol. III, No. 7, 1901.

nished the sole material used for lead pencils throughout the world. It was also forbidden by law to send any of the graphite obtained there out of the country except in the form of lead pencils.

Although the Borrowdale graphite was of a high grade it contained some impurities and the pencils made from it in the raw state were undoubtedly inferior to those now manufactured from refined material. When a harder pencil was desired it is said that the graphite strips were heated in molten sulphur before being placed between the grooved pieces of wood.

In 1795 Coute, a Frenchman, conceived the idea of pulverizing the graphite and mixing it with a binding clay, then moulding it to the desired shape and size and baking it. In this way he was able to produce a much more uniform product and by changing the proportions of clay was able to produce different degrees of hardness. The graphite sticks were placed between grooved pieces of wood as had been done before. Since then there have been many improvements in pencil manufacture with the purpose of producing more uniform and varied kinds of pencils adapted for different purposes and great improvements in the machinery used but no important changes in the process. Machinery has now almost entirely replaced hand labor in pencil making and improvements are still being made continually so that less hand labor is now required to make 100 high grade pencils than was necessary to produce a single one before the introduction of machinery. This is true regardless of the numerous processes and machines through which the pencil materials pass before completion.

In the manufacture of lead pencils it has been found that only certain varieties of graphite are suited. The flake graphite such as occurs in Pennsylvania is not desirable as the flakes would yield a "lead" that would slip over the paper without making a distinct streak and no amount of grinding could convert it into the fine pulverulent condition required for the best results. Therefore the amorphous graphites are used in the manufacture of lead pencils and the material comes mainly from Mexico, Bavaria, and Bohemia. For some years after the exhaustion of the Borrowdale deposit, graphite for lead pencils was extensively mined at Batougal, near Irkutsk, Siberia, but that deposit has long since been worked out.

The only additional requirement of the graphite for pencils is that it be pure and especially free from harder minerals such as quartz, which is called "grit."

Various binding materials have been used for mixing with the graphite, such as various mucilaginous substances, sulphur, wax, tallow, resin, etc., but no one of them seems to produce as desirable results as clay. The clay used is largely imported and is a highly plastic fire clay. Besides these two products some pencil makers mix other

ingredients such as charcoal, lamp black, etc., but their formulae are secret. Also the proportions of clay and graphite vary with different manufacturers and with the purposes for which the pencils are to be used. For soft pencils the relative proportion of graphite is increased but the amount of clay probably always exceeds the amount of graphite. In some pencils twice as much clay as graphite is used.

The graphite and clay with sufficient water to make the mass plastic, are thoroughly ground and mixed in special machines similar to the bread kneading machines used by bakers and then forced under great pressure through small tubes of the size and shape of the "lead" desired. These are cut in suitable lengths, packed in graphite crucibles, and then sent to the kiln where they are baked. To avoid making the "lead" brittle much care is required in the burning and pencil makers state that the best results are obtained by heating the furnace slowly and gradually. The temperature is carefully regulated and is much less for soft pencils than for the hard varieties. In fact the hardness of a pencil is due to the degree of temperature at which it is calcined more than to the proportions of the ingredients used.

The wood most generally employed in pencils is red cedar although poplar is sometimes used for the cheaper grades. The following excerpt from a recent bulletin of the United States Forestry Service discusses the use of red cedar for this purpose fully.

"Red cedar is the best lead-pencil wood. Pencil manufacturers procured it in the United States 100 years ago, though at that time the wood was so abundant and the demand for pencils so small that the cut for that purpose was almost negligible. The makers of pencils in Germany took measures long ago to provide this wood without the expense, trouble, and uncertainty of importing it, and planted red cedar. The plantings have thrived, but they fall short of furnishing European manufacturers what they need of the wood, and the United States is still called upon to furnish the principal supply.

"Though red cedar was one of the earliest trees to claim the attention of foresters in this country, it has not been much planted for commercial purposes, and the natural growth is depended upon to meet the demands. Pencil manufacturers can afford to pay higher prices for good cedar than most other manufacturers, and in consequence the choice wood goes to them. They often buy it by weight, and the price ranges from 30 to 40 cents a cubic foot, or about 1 cent a pound. The annual demand in this country reaches 110,000 tons, which makes 320,000,000 pencils. The cost of cedar per pencil is about three-fourths of a cent. This is because as much

as three-fourths of the pencil wood purchased never actually enters a pencil, but goes to the waste heap, or is worked into some by-product, as carpet paper or packing shavings. It is estimated that 70 per cent. of the bulk and 90 per cent. of the weight of pencil cedar purchased goes to the waste pile. It is thus apparent that the pencil maker is one of the most exacting manufacturers who work in wood. The wood must be soft, and this causes rejection of cedar growing outside of a certain limited region in the South. The grain must be straight and free from knots, and this excludes all but clear trunks, though cedar boles are not usually clear many feet of their length. Red rot must be rejected, and this often causes loss of a large part of a log. Black specks, due to old dormant buds, lessen the value of the wood, but do not prevent it from going into cheap pencils. The sapwood and some of the heartwood which is not quite up to the standard for pencils frequently goes to the penholder maker; but the demand is small, and much of that class of wood is destroyed because unsalable. In the past the sapwood was frequently got rid of by allowing it to rot. To hasten the process, the logs were buried under water until the sapwood softened, when it was more easily removed. The process improves the heartwood by softening it and making it brittle, qualities appreciated by pencil makers. At present both sapwood and heartwood are used in pencil making.

"The search for pencil wood has been widespread and thorough. Formerly new supplies could always be found by going a little farther back, but the time has now come when virgin stands need not be expected. Cedar cruisers have explored all important districts, and first-class timber has nearly all been cut. Old cuttings have been gone over; logs and trees passed by in early years are now taken. Even old stumps are cut, and some first-class wood is thus obtained. The barns and cabins built of cedar logs and planks many years ago are not escaping the searchers, and the pencil makers buy this wood in large quantities. Fence rails and pickets go the same way. In some cases the pencil men secure old cedar rail fences by constructing in their places modern woven-wire structures.

"A wide and vigorous search for substitutes for red cedar pencil-wood has been going on for years. Use of a number of woods has been made, but a substitute in all ways satisfactory has not been announced."*

In order to remove the sap and so prevent later shrinkage the wood is thoroughly steamed and dried after having been cut into small slabs of the proper length for a pencil and of a sufficient width for four, five or six pencils. These slabs are then grooved lengthwise by machinery, the groove being the exact size and shape of the "lead" which it is to receive. The "leads" are placed in the grooves

*U. S. Dept. of Agric., Bur. of Forestry, Bull. No. 95, pp. 27-29, 1911.

by girls who have acquired great dexterity through practice and the block passed to a boy who glues to it another block similarly grooved. These blocks are then placed under pressure and allowed to thoroughly dry. Shaping machines then cut the individual pencils from the blocks and they are ready for the further operations of polishing, varnishing, stamping, fitting with tin tip and rubber, sorting and packing. In the modern pencil factory practically all of these operations are done by machines and their perfection is marvelous.

PAINTS.

Graphite is extensively used in the manufacture of paint and is well suited for that purpose because of its inertness. It is practically unaffected by heat or any corrosive agents and when properly mixed with oil forms a strong air-tight film effectively protecting surfaces of wood or metal from atmospheric action. It is usually mixed with other pigments, such as red lead and sublimed blue lead, while good linseed oil constitutes the medium of suspension. Both natural and artificial graphite is used for paint but it seems probable that the natural flake graphite forms a smoother, stronger film by the overlapping of the flat particles.

Because of its color, the use of graphite paint is mainly limited to steel bridges, stand pipes, tin roofs and steel structures of various kinds. For these purposes it has long been regarded as excellent material and certainly there is much reason for believing it to be well adapted for such purposes. However, in recent years objection has been made to graphite paint for use on steel on the ground that it stimulates corrosion. Both the American Metal Workers' Association and the Paint Manufacturers' Association of the United States state that it should not be used as a priming coat for steel. Graphite manufacturers claim otherwise and they have many supporters among those who have extensively used graphite paint so the question of its value when applied directly to metal must be regarded as unsettled.

The following quotation originally printed in The Painters' Magazine presents the view point of the graphite paint manufacturer.

"For many years it was generally conceded that graphite paint was the best paint for the protection of tin roofs, but of late years opinions have differed much on that point, a prominent tin plate manufacturer taking the ground that a galvanic action is produced between the carbon of the graphite and the tin that acts destructively upon the iron. In reply to this, a well known manufacturer of graphite paint says:—

'There has been of late a good deal brought out with regard to the tendency of different pigments to increase the corrosion of iron

or steel plate. It is perhaps so, that carbon shows a more stimulating action so far as a laboratory test is concerned. We have made some tests ourselves, and while the results are not entirely confirmatory, there are indications in this direction. But the success of graphite paint is based, not upon laboratory experiments, but upon actual service. We think that it is a fact that at the present time graphite and carbon as a paint pigment stands in the very first rank so far as their use as a pigment for protective coating is concerned, but the essential thing to be considered is, not only whether graphite actually accelerates corrosion when lying in contact with iron and steel in connection with moisture, but whether the paint film, when formed of a proper thickness, is a more durable one than when made with other pigments. We think it is a fair statement to make that corrosion on any structure is the result of a wearing away or a destruction of the paint film itself.

'Proper care is not taken to inspect the coating and to provide for repainting at proper times, with the result that the paint covering has often disappeared and corrosion sets in before repainting is resorted to. There is no question whatever about the extreme durability of the carbonaceous coatings. We don't think any one questions the fact that so far as the durability of the paint skin itself is concerned, that they stand away ahead of paints made with other pigments.

'Probably the one great weakness of graphite paints is the fact that they are spread out easily, and when a painter runs against them for the first time, he observes that they are apparently very heavy and he immediately proceeds to add some thinner, and, of course, under these circumstances he gets such results that the manufacturer tries to provide against. When he makes his paint so heavy the painter goes on thinning and he secures a coating which may be only one-half as thick as he would have secured had he applied an iron oxide paint. The manufacturer of graphite paint never had any trouble whatever with tin roofs until the manufacture of tin plate was developed in this country. There is undoubtedly a good deal of pretty fair tin plate made in this country, and there is a great deal that is unfit for service. The fact that a large number of the complaints made may be laid to the tin plate itself, is evidenced by the fact that on a roof you will find perhaps an equal number of plates which show no sign whatever of corrosion, intermixed with an equal number which are very badly pitted. Such a condition as this can only be explained by a lack of uniformity in the quality of the plates themselves. But to anyone who has a doubt on this matter of painting tin roofs, there is a course open which should be entirely satisfactory. Let him first paint the tin with a coating of paint containing an oxide of some metals, red

lead or iron oxide. Then let him protect that with a coating of graphite or carbonaceous paint. After this has been done, there can be no trouble whatever about his securing a satisfactory result.' "*

LUBRICANTS.

Although the properties of graphite have long been known, new uses based upon its peculiar properties are continually being found. One of the comparatively new enterprises which now has reached great proportions is its use as a lubricant. This was practically begun only about 35 years ago and now about 5% of the total production is so utilized and graphite lubricants seem to be continually growing in favor. The unctuousness or soapy feeling of the graphite, the flexibility of the flakes, its softness, its ability to resist high temperatures and corrosive agents, and its high heat conductivity which assists in keeping the bearings cool, are the properties which render graphite valuable as a lubricant. It fills all irregularities in the bearings and forms a smooth coat which reduces friction to a minimum. It can be used where oil is not serviceable, as for example, in cases where the pressure on the bearings is great and the movement so slow that the oil would be squeezed out. In textile machinery where the oil might ruin delicate fabrics it isespecially serviceable.

The flake graphite is generally held to be better adapted for use as a lubricant than the pulverulent or amorphous varieties, although much artificial graphite is so used. Much of the Pennsylvania graphite is made into lubricants.

For certain purposes the graphite is used dry but usually is mixed with oil or some other liquid in order to facilitate its application. Different preparations are made for different types of machinery and various ways have been devised for applying it.

ELECTRICAL PURPOSES.

Because of its high electrical conductivity and the high temperature at which it is oxidized, graphite articles find wide and varied applications in electrical work. It is used among other purposes in the manufacture of dynamo brushes and resistance rods, electric light carbons, electrodes, rheostats, in dry batteries, facing the moulds used in electroplating, etc. All grades of graphite, particularly the amorphous and artificial, are used in electrical apparatus.

COVERING FOR POWDER.

The grains of gun powder are glazed with a coating of graphite to prevent absorption of moisture and consequent caking. This is done by putting the graphite and powder in a large barrel and

*Graphite, Vol. XII, p. 2098, Jan. 1910.

shaking them together thoroughly for several hours. Graphite has also been used to coat high explosives to prevent the formation of static charges of electricity and consequent sparking.

FERTILIZER FILLER.

Amorphous graphite is used as a filler in certain manufactured fertilizers. Its value for such purpose is said to be due to the fact that it prevents the absorption of moisture and the consequent caking of the mass. The fertilizer after being ground remains in the form of powder thus permitting it to be more evenly and easily spread over the fields. Further, the addition of graphite to the fertilizer increases its market value as many users of fertilizer have an idea that dark colored fertilizers possess greater strength. If added for this purpose the graphite is simply an adulterant as it cannot be utilized by plants.

OTHER MINOR USES.

Graphite is used to color and glaze tea leaves and coffee beans to protect them from moisture and to add to their attractive appearance. It is used in the manufacture of printer's ink and dye for felt hats. It is used in dressings for belts, for steam packing instead of asbestos, and in the manufacture of stove or boiler cements. It is also known that a small amount of graphite added to water used in boilers will prevent boiler scale.

In addition to the above-mentioned uses, graphite as a minor substance enters into the manufacture of countless other products, many of which are similar to those already described.

CHAPTER VI.

DISTRIBUTION OF GRAPHITE IN THE UNITED STATES.

That graphite is not a rare mineral is shown by the fact that the greater number of states of the Union have produced it at one time or another. Practically every state that contains metamorphic rocks contains graphite and in most of such states it is found in large enough quantities to be worked with profit or at least to warrant careful investigation.

In view of this wide distribution it is unfortunate that the United States is still unable to supply the demand and that the imports of this useful mineral continue to surpass the output. This is partially due to the fact that no grade of graphite has thus far been found in the United States that possesses certain of the desirable qualities

of the foreign graphites. Ceylon graphite would still be imported for crucibles and Mexican or European graphite for pencils, in all probability, even though the output of our mines should be increased several times.

The graphite of the United States belongs to the two classes: amorphous and crystalline. The greater portion of the graphite-producing states furnish the amorphous variety alone but some produce both while New York and Pennsylvania produce crystalline graphite alone.

The brief descriptions of the graphite deposits of the various states that follow is obviously somewhat incomplete but in a general way it represents what is known of the graphite of the United States at the present time.

*ALABAMA.**

"Graphite is widely distributed among the metamorphic rocks of Alabama,† in which it occurs in two forms: (1) In the feebly crystalline schists which have been called the Talladega States,‡ and which in part at least are Paleozoic sediments of as late age as the 'Coal Measures,' graphite is often found as a black graphitic clay free from grit. In this condition the graphite is difficult to separate from the other matter with which it is mixed and the material has not as yet been utilized commercially to any important extent. Examples of this mode of occurrence may be seen near Millerville, in Clay county, and about Blue Hill, in Tallapoosa county. (2) In the mica schists and other highly crystalline rocks graphite is found in the form of thin crystalline flakes which may be separated from the associated minerals. Graphitic schists of this type are now being worked at three localities and have in the past been worked at several others.

"The more important localities where flake graphite occurs were visited by the writer in the spring of 1911 and are briefly described below.

CLAY COUNTY.

"The two counties which are at present the leading producers in Alabama are located $4\frac{1}{2}$ and 8 miles west of Ashland. Ashland, the shipping point, is the terminus of a short branch of the Atlanta, Birmingham & Atlantic Railroad. This branch is 7 miles long and joins the main line at Pyriton. The freight rate on refined graphite from Ashland to New York City is about $7 per long ton.

"*Allen Graphite Co.*—The quarry and mill of this company, which at present is the largest producer in the State, are located a little over 8 miles west of Ashland, at a settlement shown on the United

*Bastin, E. S., Min. Res., 1910, U. S. Geol. Survey, pp. 903-907.
†E. A. Smith, Min. Industry, Vol. 16, 1907, p. 568.
‡H. McCalley, Geol. Survey, Alabama, Rept. Valley regions, Pt. 2, 1897, pp. 36-38.

States Geological Survey's map of the Ashland quadrangle under the name 'Graphite.' The mine is about one-half mile from the mill, with which it is connected by a tramway. The concentrate is hauled over a fairly good road to Ashland for shipment. The mining is entirely from open pits, and because of the decomposed character of the rock can be accomplished largely with the aid of pick, shovel, and crowbar, without much drilling and blasting. The main pit is about 450 feet in length, 100 feet in average width, and about 60 feet in maximum depth. A small pit just east of the main pit and on the same graphitic band is about 100 feet long, 90 feet wide, and 25 feet deep. A third pit has been opened on the same band of graphitic schist about 1,000 feet east of the main pit on the west face of another hill. This is about 90 feet wide, about 200 feet long, and about 40 feet deep. The strike of the schist at the north end of the main pit is N. 80° E., with a dip of 75°S. This is fairly typical for the deposit as a whole.

"The rock mined is highly schistose and is composed largely of quartz and graphite. A white, fibrous mineral, probably sillimanite, is also abundant. Feldspar and mica are rare. Few of the thin graphite flakes so far seen by the writer exceed 2 millimeters across and most of them under 1½ millimeters. They are arranged sub-parallel to one another, and to this arrangement and a similar orientation of the sillimanite (?) prisms is largely due the schistosity of the rock. At the west end of the main pit a dike of coarse granite, 1 to 1½ feet wide, parallels the foliation of the schist, and in the easternmost pit the graphitic schist has also been intruded by an irregular body of coarse granite pegmatite carrying muscovite crystals up to 3 inches across. The graphite beds here are also disturbed by faulting. The contact metamorphic effects of these small intrusions on the graphitic schist appear to be slight.

"The milling process is divided into three principal stages: (1) Crushing and drying; (2) preliminary wet concentration, and (3) final dry concentration.

"The most important step in the milling process is the preliminary concentration by water flotation. In these concentrators the dry crushed rock is spread in a thin stream upon the surface of slowly flowing water. The graphite being flaky is supported by the surface tension of the water and floats off while the granular gangue, mainly quartz, sinks and is sent to the dump. The process is cheap where water is plentiful. The tailings seen on the dump carry suprisingly little graphite; that which is present is usually attached to other minerals. Much fine grit of course floats off with the graphite but is removed in the final dry concentration.

"The crude rock is said by the operators to average about 5 per cent. graphite. For two successive years (September, 1908, to Sep-

tember, 1910), the finished product formed, respectively, 2.95 and 2.7 per cent. by weight of the crude rock treated. Four principal grades are produced whose relative proportions are about as follows:

GRADES OF FLAKE GRAPHITE PRODUCED BY ALLEN GRAPHITE CO. CLAY COUNTY, ALABAMA.

		Per cent.
Grade C.	Crucible flake	36
Grade 1.	Lubricating flake (coarse)	11
Grade 2.	Lubricating flake (fine)	18
Grade D.	Dust for foundry facings, etc.	35
		100

"The highest grade contains over 90 per cent. graphite; the dust averages about 50 per cent. graphite. The prevailing average prices f. o. b. New York are: Grade C, 6½ cents per pound; grade 1, 5½ cents per pound; grade 2, 4¼ cents per pound; and grade D, 1 cent per pound.

"*Ashland Graphite Co.*—The quarry and mill of this company, which is the sucessor to the Enitachopco Graphite Co., are located about 4½ miles west of Ashland. The product of the plant is hauled by team to Ashland. The workings at this property consist of two open pits located in the same belt of graphite schist. The two pits are on neighboring knolls, and the mill is in the small valley between them. The largest or eastern pit is about 400 feet long, 30 to 50 feet wide, and 50 feet deep. It follows along the strike of a band of graphitic schist which averages about 30 feet in width, though broadening locally to about 50 feet. The strike is about N. 55° E. and the average dip is about 45° E. The second pit, located west of the mill, is about 150 feet long, 20 feet wide, and about 20 feet deep. The trend of the schists is similar to that at the larger pit.

"The graphitic rock at this quarry is similar in general to that at the Allen quarry. The schist is too much decomposed for the complete identification of all the minerals, but quartz is the principal component. As a rule mica is rare, but the brown mica biotite is common in a few places. The graphite forms thin flakes, mostly under 1 millimeter in diameter, although some reach 2 millimeters. No igneous rocks were seen in association with the graphitic schist at this property. The rock being more or less decomposed can be excavated with pick and crowbar with occasional blasting. It is loaded into tramcars and hauled to the mill.

"The mill has a capacity of about 50 to 60 tons per day of 12 hours. The milling process is in general similar to that at the Allen mill,

though differing in details. A dry pan is used in preliminary crushing. The water flotation separators are similar to those at the Allen plant. The final dry concentration is accomplished by screens and buhrstone mills without the use of Hooper pneumatic concentrators.

CHILTON COUNTY.

"*Dixie Graphite Co.*—The property of this company is about 6 miles northeast of Mountain Creek, the shipping point, a small station on the Louisville & Nashville Railroad. The company has been out of business for many years and the mill is partly ruined. Two Jeffrey vibratory screens and a rotary drier are all that remain of the milling machinery. The graphitic rock was taken from several small open pits and a short tunnel on the slopes of a small creek valley. The creek is of sufficient size to furnish water for wet concentration but not for power. The tunnel is about 50 feet long and is enlarged at its end to a room about 50 by 50 feet and 15 feet high. The rock is a graphitic quartz schist interbanded with schist rich in muscovite. The general strike is about N. 70°W., and the dip is about 60°N. Quartz lenses are abundant. The graphitic portions are pockety in their distribution, and the flakes are small. For these reasons and because of its distance from the railroad the property is much less promising commercially than others in the State.

"*Flaketown Graphite Co.*—This company operates a quarry and mill in the valley of Chestnut Creek, about 3½ miles northeast of Mountain Creek station. The property is about 3 miles west of that of the Dixie Graphite Co. The graphitic rocks lie in the west valley slope and have been developed by a small open pit. South of this pit sufficient prospecting has been done to show that the deposit is of very considerable size. The rock is a graphitic quartz schist very similar to those worked in Clay county. On account of its situation on a steep valley slope, which favors relatively rapid removal of weathered material, the remaining material is not so much decomposed as the deposits west of Ashland, in Clay county.

"Small quantities of green micaeous mineral, probably muscovite, are present in some specimens, but in general, mica is rare. The strike of the schist folia at the main pits is N. 35°W., with a dip of 45°S.W. A few hundred yards farther south the strike shifts to N. 20°W. and N. 15°W. A dike of granite pegmatite 1 foot wide intrudes the graphitic schist at the main pit. It parallels the foliation, and within 1 to 2 inches of the schist carries graphite in scattered flakes up to one-eighth of an inch in diameter.

"An analysis made by the United States Geological Survey of a composite sample of graphitic schist, collected from a number of different exposures on this property, showed 4.63 per cent. of graphite.

"The mill is located at the quarry, and during part of the year electric power for its operation is generated by water from a 20-foot dam on Chestnut Creek. Auxiliary steam power is also installed. The details of the concentrating process were not observed. Very little material has yet been marketed, the plant being still in an experimental stage. Mountain Creek is the nearest shipping point.

COOSA COUNTY.

"A graphite prospect is located about 2 miles northwest of Goodwater, a station on the Central of Georgia Railway. At this locality a large number of small prospect pits are scattered over an area of several acres, and nearly all show graphitic quartz schist. The prospects are on a steep southwest hillside overlooking the iron bridge where the wagon road from Goodwater to Pine Grove crosses Hatchet Creek. The rock is gray when fresh and highly schistose and strikes nearly east and west, with a dip of about 45°S. It is almost identical in character with the graphitic schist worked in Clay county and consists largely of quartz and graphite, the latter in flakes mostly under 1 millimeter in diameter. Very little mica is present. An analysis of a composite sample of graphitic schist collected from a large number of pits on this property showed 2 per cent. of graphite, but in certain portions the percentage will undoubtedly be greater. The deposit is unquestionably a large one and its situation on a steep hillside would afford opportunity to work to a considerable depth by open-pit methods. The neighboring Hatchet Creek would furnish abundant water for wet concentration of the graphite.

"A second deposit, probably of similar character, has been prospected between Mount Olive and Hollins. It was not visited by the writer, but is said to be of considerable size."

*ALASKA.**

"Extensive graphite deposits occur in Alaska on both the northern and the southern slopes of the Kigluaik Mountains in the southern part of Seward Peninsula. On the south side of the range between Grand Central and Windy Creeks† a sharp ridge is made up of biotite schists striking east and west intruded by dikes and sills of granite and pegmatite. Some of the schists are highly graphitic, the graphite occurring as abundant small flakes, much of it not distinguishable on casual examination from biotite. Locally graphite is segregated in beds of much flattened lenticular form lying in the

*Min. Res., 1909, U. S. Geol. Survey, Pt. II, pp. 818-819.
†Moffit, Fred. H., The Nome Region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 139-140.

cleavage of the schist and reaching thicknesses of 6, 8, or even 18 inches. Thin beds of schist with numerous large garnets are included, and quartz is nearly everywhere present.

"The sills and dikes of pegmatite which cut the graphitic schists also contain graphite. The graphite in these appears to have crystallized at the same time as the other pegmatite minerals. At one place about 8 inches of solid graphite is included between a pegmatite sill and the overlying schist. The steep slopes of the mountains are strewn with loose fragments. One block of approximately 7 feet by 6 feet by 30 inches consisted of about equal amounts of schist and apparently almost pure graphite. These deposits are on the south side of the range and have not been developed.

"On the north side of Kigluaik Mountains* deposits of graphite occur, upon which some development work has been done. One firm—the Alaska Graphite Company, of San Francisco—has shipped considerable quantities from this locality to the United States. At this place graphitic schists are interlaminated with more quartzose biotite schists. Both are intruded by granitic rocks. Much of the graphite is obtained in 'blocks' 2 feet in length and 1 foot in thickness, practically unmixed with foreign material. Dislocations and fractures make the stoping out of the ore more or less dangerous. After the ore is broken from the ledge it is cobbed and hand sorted. In this sorting less than 25 per cent. of the material is retained. This is sacked and hauled down the steep slope of the mountains on sleds to the flats surrounding Imuruk Basin. The sacks are then transported by horses to the shore, where they are put aboard a boat and taken to Teller for shipment. The Alaska Graphite Company continued development work during 1909. The small quantity imported was ground in San Francisco and sold principally for foundry facings. All of the material shipped was crystalline so far as known. It is said to average from 50 to 75 per cent. graphite."

ARKANSAS.

Graphite has been reported† from a locality 2 miles north of Mountainsburg, Crawford county, where some development work has been done. Later information, however, has shown that the material is not graphite. So-called graphites have also been worked for paint materials in Garland, Montgomery, Hot Springs and Polk counties.

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*Smith, Philip S., Investigations of the mineral deposits in Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, p. 250; Also Recent Developments in Southern Seward Peninsula, Bull. U. S. Geol. Survey No. 379, 1909, pp. 300-201.

†Min. Resources for 1910, U. S. Geol. Survey, p. 909.

CALIFORNIA.

Graphite has been reported from many places in the Sierra Nevada and Coast Mountains of California, but there have been few attempts to mine it. The State contains deposits of both amorphous and crystalline graphite but mainly the former. It has been mined to a limited extent in Sonoma and Mendocino counties. Promising deposits are said to occur in the northern part of Shasta county.

*COLORADO.**

"Amorphous graphite is mined in Colorado by the Federal Graphite Company about 2 miles northeast of Turret in Chaffee county. The mine is situated on the west slope of Graphite Hill, within about a mile of the stage road from Salida to Turret (14 miles), and was visited by the writer in the summer of 1909.

"The present workings consist of two inclined shafts located about 100 feet apart on the same lode. The incline shafts have been sunk to a depth of 40 to 50 feet and some drifting and stoping has been done. A tunnel is being driven about 125 feet below the mouths of the inclines, from which a raise will be made to the graphite bed. The work is done by hand drilling.

"The graphite occurs in one principal and a number of subordinate beds interbedded with white to gray crystalline limestone, buff-colored quartzite, and dark-gray to purplish quartzitic schist. The sediments and associated graphite beds strike about north and south and dip to the east at from 30° to 40°.

"The hill slope above the graphite beds is occupied by a gray to purplish quartz-schist, but just over the crest of the hill and not more than 500 or 600 feet east of the graphite a large area of gneissic biotite granite is reached. Fine-grained granite occurs as a dike cutting the sediments within a few feet of the main graphite bed at the mouth of both of the inclines, and a tongue of graphite granite a few inches wide was observed penetrating slightly graphitic material just beneath the productive graphite bed.

"The main productive bed as now exposed varies from 3 to 4 feet in thickness, somewhat more than half of this thickness consisting of the second grade of ore, which is lower in graphite than the first grade, higher in clayey material, and of a grayish or purplish tint. The first grade of graphite is dull black and very pure, the purest portions showing a somewhat foliated structure. Both grades are very fine grained and earthy and are properly classed in the so-

*Bastin, E. S., Min. Res., 1909, U. S. Geol. Survey, Pt. II, pp. 819-820.

called amorphous group. In the northern incline a second bed 1 foot thick of first-grade ore was exposed about 4 feet above the main bed. What appears to be the same graphite bed has been prospected north and south along the slope of Graphite Hill for about a mile. In the southern incline graphitic beds are separated by a bed of crystalline limestone, tapering from a thickness of 2½ feet to 8 inches in a distance of about 20 feet.

"It is evident that this graphite was originally coal and highly carbonaceous shale interbedded with sedimentary rocks. The coal has been converted into graphite and its inclosing sandstones and limestones into quartzite, quartzitic schists, and crystalline limestones through the heating and other contact metamorphic effects of large masses of granite which have been intruded into the sediments. The granite and granite gneiss occupies most of the country between this mine and Turret and forms large areas south and east of the mine.

"The first-grade graphite is packed in bags; the second grade is shipped in bulk. It is hauled 5 miles, mostly down hill, to a siding on the Denver and Rio Grande Railroad and shipped to the mill of the company at Warren, Ohio. Here it undergoes fine grinding and is sold for use as paint pigment, in stove polishes, for lubricants, foundry facings, etc. Some of the best grade has been used in the manufacture of lead pencils."

CONNECTICUT.

Graphite occurs in many places in Connecticut in the highly metamorphosed pre-Triassic crystalline rocks. It is usually found in small amounts disseminated through the metamorphic rocks and possesses no value. In the Brimfield schist which covers considerable areas in the Eastern portion of the State "graphite occurs in small fragments with metallic luster, and occasionally in sufficient abundance to attract a prospector. Abandoned 'lead' mines are found in parts of Ashford, Union, and Mansfield, as well as farther north, in Massachusetts."*

GEORGIA.†

Graphite has been observed in many places in Georgia but has been mined in few sections. The most important locality is near Emerson, Bartow county, where two companies have been operating for several years. The formation is a graphitic talcose slate which forms a nearly continuous belt from a few hundred yards to several miles in width and extends for many miles. The rock was originally

*Rice and Gregory, Manual of the Geol. of Conn., p. 127, 1906.
†Hayes and Phalen: U. S. Geol. Survey, Bull. No. 340, pp. 463-465.

a carbonaceous clay shale which has undergone intense metamorphism producing graphite and talc. The graphite is amorphous and is in such fine particles that no attempt is made to separate it from the associated impurities. The rock contains from 2 to 5% carbon. The rock is quarried, crushed, ground, and shipped to fertilizer plants for use as a fertilizer filler. It sells at $1.25 to $1.50 f. o. b. at the mill.

*IDAHO.**

Amorphous graphite has been mined near Ketchum, Blaine county, but no definite information regarding the occurrence and value of the deposit is available.

MAINE.†

Graphite has been reported from several localities in the crystalline rocks of Maine but in no place, so far as known, are these deposits of sufficient importance to warrant the operation of mines. Two localities have received some attention and are worthy of mention. The most important deposit is located near Madrid, Franklin county. During the summer of 1905 some development work was carried on there by the Maine Graphite Company but with indifferent success. The graphite occurs in a quartz-biotite schist in close contact with intrusive pegmatite dikes. The schist contained originally some amorphous or extremely fine-grained crystalline graphite which was later crystallized into larger particles by the heated vapors accompanying the intrusive rock magma. Some specimens of ore contain as much as 8.5 per cent. graphite.

A second locality for graphite is about one-half mile northwest of the village of Yarmouth, Cumberland county. The graphite occurs in a pegmatite dike with an average width of one foot. It has been prospected for a distance of 200 yards. "The pegmatite is for the most part of medium grain, and quartz and feldspar are the principal constituents. Small amounts of mica occur, but only sporadically, while graphite is an important constituent. A few nests of graphite about an inch in diameter occur in the pegmatite, but the most of the graphite is in the form of disseminated flakes evenly distributed throughout the rock. No definite difference between the content of graphite near the walls of the dike and that at the center could be noted, nor was any variation noticed in the amount near the contact with the basaltic rock." The graphite is believed to be of magmatic origin.

*Min. Resources for 1909, U. S. Geol. Survey, Part II, p. 833.
†Smith, G. O., Bull. No. 285, U. S. Geol. Survey, pp. 480-483.

MASSACHUSETTS.

Hitchcock in his reports on the geology of Massachusetts published in 1832, 1833, and 1841, describes a graphite mine at Sturbridge which had been recently re-opened after having been long abandoned. Work seems to have been continued for many years as the vein has been worked to an average depth of about 60 feet to a distance along the outcrop of about 3000 feet. It was abandoned for many years but within recent years a small amount has been taken out several times and efforts are now being made to re-open the mine. It was recently pumped out and some graphite removed. One piece of ore taken out is said to have weighed over 500 pounds.

The graphite occurs in the form of a vertical vein varying from 1 inch to 6 feet with an average of about 2 feet. The graphite is of excellent quality and occurs in the form of lamellae and fibers closely resembling the Ceylon graphite. In composition also it is about as pure as the Ceylon product, some selected specimens analyzing over 98% carbon.

Graphite also occurs in several other places in the State but not in commercial quantities, so far as known.

MICHIGAN.

The Detroit Graphite Company has operated a quarry near Taylor, Baraga county, Michigan, for several years. The material obtained is a graphitic slate with a high percentage of carbon, averaging about 30%. The graphite is largely amorphous although some occurs in extremely fine crystalline flakes. No attempts have been made to separate the graphite from the associated minerals and it is doubtful whether it could be economically concentrated. The rock is ground fine and used in the manufacture of paint.

The rock is quarried during the summer season and hauled on sleds to the railroad station during the winter for shipment to Detroit. During the season of 1911 about 2700 tons of rock were quarried.* The supply is very large but the demand is limited.

Other companies have operated in the same region in the past.

Analysis of graphitic rock from Baraga county, Mich.†

Carbon, graphitic (C)	28.39
Silica (SiO_2)	46.97
Alumina (Al_2O_3)	16.90
Iron, soluble, as Fe_2O_3	0.41

*Min. and Eng. World, Vol. XXXV, p. 1226.
†Min. Resources, 1909, Part II, p. 820, 1911.

Iron, insoluble, as Fe_2O_3	3.81
Calcium (CaO)	0.47
Magnesium (MgO)	0.52
Water, uncombined (H_2O)	0.13
Carbon dioxide, combined water, sodium compounds, loss, and undetermined matter	2.40
	100.00

The United States Graphite Company, with extensive mines of amorphous graphite in Sonora, Mexico, treats its product at Saginaw, Michigan.

*MONTANA.**

The known graphite deposits of Montana are located about 15 miles southeast of Dillon where considerable development work has been done with promising results. The graphite is very pure. The region is of interest because of the different ways in which the graphite occurs. Winchell describes the following occurrences: (1) as seams an inch or two in thickness strictly parallel with the bedding, (2) in veins and faults as lenticular masses 6-8 inches in thickness and 2 to 4 feet in diameter not parallel with the bedding, (3) intimately associated with quartz, feldspar and mica forming a graphitic gneiss, and (4) in pegmatites. The principal country rock is the Van Camp limestone of early Paleozoic age.

NEVADA.

"The Carson Black Lead Mining Company is manufacturing various practically fire proof paints from the output of its mine, which is located 3 miles south from Carson. A deposit 4,500 feet in length and 6 feet in width, 90 per cent. pure graphite, has been opened up. It is one of the largest deposits in the West and one of the purest in the United States.† A recent report from this company states that the ore contains 40% carbon.

NEW HAMPSHIRE.

Graphite occurs in the old crystalline rocks of New Hampshire in many places and has been mined near Nelson, Cheshire county, and Goshen, Sullivan county. It is said to be of inferior quality.

"Large specimens are found at Bristol. In Chester, it is found in veins in the mica slate. On the north side of Monadnock Mountain,

*Winchell: Bull. No. 470, U. S. Geol. Survey, pp. 528-532, 1911. Rowe: Bull. No. 50, Geol. Ser. No. 3, Univ. of Montana, p. 66, 1908.
†Ann. Rep. State Inspector of Mines, Nevada, 1910, p. 58, 1911.

nodules with a coarse texture are found. At Sutton much is found and of good quality. Other localities are Barrington, Bedford, Troy, Walpole, Washington, Hillsborough, Campbell Mountain, Keene, Wentworth, Swanzey, Andover, and Oxford."*

NEW JERSEY.

Graphite occurs in many places in the crystalline rocks of northern New Jersey and numerous attempts have been made to mine it but none of them have been commercially successful.

Bayley† states that the graphite occurs in four ways in the Highlands of New Jersey and New York as follows:—

"1. As a component of the Franklin limestone, which is a white crystalline pre-Cambrian rock.

2. In bands of garnetiferous mica gneisses that may, in some instances, represent altered fragmental rocks, but which, in other cases, are certainly mashed pegmatites.

3. In coarse-grained granite dykes or pegmatites.

4. In fine-grained quartzite micaceous schists, especially where these are associated with pegmatites."

The last mentioned method of occurrence is the most important and attempts have been made to mine such schists and gneisses rich in graphite. Concentrating mills were built at Bloomingdale, Brookside and High Bridge but in each case the venture was a failure. The State Geologist of New Jersey‡ describes the High Bridge locality as follows:—

"The most recent experiment was made at High Bridge last year (1907) where a graphite-bearing bed of gneiss 30 to 50 feet wide was opened by a tunnel driven along the strike of the bed for a distance of about 400 feet. The ore-bed is reported to dip 70° westward with a strike west of north. It is covered by about 6 feet of soil, mostly disintegrated rock. Pronounced weathering extends to a depth of 30 feet. The ore was reported to contain from 4 to 8 per cent. of graphite and the mill test gave about 4 per cent. extraction, but considerable was lost in the process. The graphite recovered was divided into four grades. The only ore mined was that taken out in driving the tunnel, and during the seven months that work was continued about three and a-half carloads of graphite were obtained and shipped. The plant was closed down in November. The enterprise seems to have been ill-advised in that a costly plant was erected before much development work had been done."

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*Hitchcock: Geol. of New Hampshire, Vol. III, pp. 25-26, 1878.
†Economic Geology, Vol. III, pp. 535-536.
‡Ann. Rep. State Geol. of N. J. for 1907, p. 177.

NEW MEXICO.

The graphite deposits of New Mexico are located near Raton, New Mexico. The description which follows is taken from a recent article by W. T. Lee in Bull. No. 530 of the U. S. Geological Survey.

"A large body of amorphous graphite occurs in the canyon of the Canadian River about seven miles southwest of Raton in Colfax County, New Mexico. The bed lies practically horizontal and has been prospected for a distance of several miles along the outcrop in the Canadian and its tributary canyons and traced laterally into the principal coal bed of the Raton field which contains bituminous coking coal. Igneous rock was forced into the coal-bearing sedimentary rocks in many places in this field and usually formed coke where it came in contact with the coal, but in the Canadian Canyon many sills were formed both above, below and in the coal bed, and apparently the sedimentary rocks were heated through a considerable thickness. The coal has been most completely graphitized where the bed was fractured and diabase forced into it. The graphite occurs in 'pockets' or irregular masses in the diabase and is more or less columnar, the columns usually standing normal to the faces of the igneous rock. The columnar parts are relatively pure while the non-columnar portions seem to have resulted from what was originally bony coal or carbonaceous shale.

"Analyses were made of this graphite by Andrew S. McCreath of Harrisburg, Pennsylvania, who reported that it contains no sulphur or other material detrimental to its use in the manufacture of paint. To test the effect the weather might have on the paint the graphite was subjected to caustic alkali and to strong acids, including aqua regia but so little effect was produced on it that it was pronounced satisfactory as a base for paint.

"The writer collected a sample of the graphite for analysis 160 feet from the mouth of an old opening at a point where the bed was about 3 feet thick. In order to obtain a representative sample the weathered material was cleared from the exposed face of the bed. The sample represents the entire thickness of the graphite at this point and therefore the analysis shows a greater percentage of impurity than would be found in pieces selected from the best material. The sample was analyzed as coal in the chemical laboratory of the technologic branch of the United States Geological Survey at Pittsburgh. It is given in the table that follows as No. 6521.

"The unmetamorphosed coal of the bed containing the graphite is mined at Van Houten, a mining camp located 4 miles southwest of the graphite opening. For purposes of comparison with the graphite

two analyses of this coal are given. The bed in the mine is 10 to 15 feet thick and in some places very little impurity occurs in the coal. In other places small amounts of shale and bony coal are encountered.

"Although the graphite was originally coal, as is clearly indicated by its position, its chemical character gives little indications of its origin and it was somewhat surprising to find 6.07% of 'volatile matter' in it,—a percentage considerably higher than some other graphites of similar origin. At the writer's request Dr. H. C. Porter made a chemical examination of this volatile matter. The results obtained by him are as follows:

ANALYSES OF GRAPHITE AND COAL SAMPLES FROM THE RATON COAL FIELD, NEW MEXICO.

F. M. Stanton, *Chemist in Charge.*

Condition of Sample.	Lab. No.	Air drying loss.	PROXIMATE. Moisture.	Volatile matter.	Fixed carbon.	ULTIMATE. Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	HEAT VALUE. Calories.	B. t. u.
Graphite as received,	6521	0.40	1.31	6.07	76.11	16.51	.17	-------	-------	-------	-------	-------	-------
Graphite air dried,			.91	6.09	76.42	16.58	.17	-------	-------	-------	-------	-------	-------
Graphite moisture free,			-------	6.15	77.12	16.73	.17	-------	-------	-------	-------	-------	-------
Graphite moisture and ash free,			-------	7.39	92.61	-------	.20	-------	-------	-------	-------	-------	-------
Coal as received,	6417	1.40	2.42	33.69	54.42	9.47	.66	5.21	72.84	1.1	10.72	7303	13145
Coal air dried,			1.03	34.17	55.20	9.60	.67	5.12	73.87	1.12	9.62	7407	13333
Coal moisture free,			-------	34.53	55.77	9.70	.68	5.06	74.65	1.13	8.78	7484	13471
Coal moisture and ash free,			-------	38.24	61.76	-------	.75	5.60	82.67	1.25	9.73	8288	14918
Coal as received,	6418	1.50	2.51	34.64	54.03	8.82	.76	5.50	73.65	1.20	10.07	7404	13327
Coal air dried,			1.03	35.17	54.85	8.95	.77	5.41	74.77	1.22	8.88	7517	13531
Coal moisture free,			-------	35.53	55.42	9.05	.78	5.35	75.54	1.23	8.05	7594	13669
Coal moisture and ash free,			-------	39.07	60.93	-------	.86	5.88	83.06	1.35	8.85	8350	15030

ANALYSIS OF VOLATILE MATTER CONTAINED IN THE GRAPHITE OF NEW MEXICO.

20 grams, as received, crushed to rice size, heated 20 minutes in atmosphere of nitrogen at 930°—950°C.

	I.	II.
Total loss (includes moisture 1.31%),	5.6%	6.0%
Water (includes moisture 1.31%),	4.22	4.23
Tar,	trace	trace
Gas: liters per kilo,	16.2	15.0
cubic feet per ton,	520	480
Composition of gas,		
CO_2,	9.1%	
Illuminants,	3.1	
CO,	9.3	
CH_4,	19.5	
H_2,	52.7	
N_2,	6.3	

This material seems to retain its graphitic streak after heating at a high temperature, which would seem to indicate that it is a true graphite; as does also the fact that it is extremely difficult to burn. The volatile matter is very largely water, which I should say is in the form of combined water or water of crystallization. This is indicated also by the decrepitation on heating.'

"The prospect from which this sample was taken was opened in 1889 by the Standard Graphite Company of New York and 250 tons of graphite were shipped from it to Moosic, Pennsylvania, where the ore was tested as to availability in the manufacture of paint. One of the objects of the company was to ascertain whether the graphite could be handled profitably and careful accounts were kept. According to the statement of one of them, it was ascertained that the graphite could be placed in the bins at Moosic, for $17.50 per ton—the greater part of the cost being shipping charges. At Moosic, at an additional cost of ninety cents per ton, it was ground and separated from some of its impurities by means of air blasts, the refined product running 80% carbon, the 20% impurity being mostly silica which was not regarded as objectionable in the manufacture of paint. The tests were satisfactory to the company and the mill was being taken apart for shipment to Raton when it was destroyed by fire and nothing has since been done toward developing the graphite."

NEW YORK.

For many years New York has been the leading graphite producing state of the United States. This position it holds mainly because of the operations of the Joseph Dixon Crucible Company. For many years the company operated mines on Chilson or Lead Hill about

2½ miles west of Ticonderoga but in recent years has confined its work to the locality of Graphite, a small village in Warren county, about 3 miles west of Lake George.

The graphite of New York occurs in the highly metamorphosed rocks of the peripheries of the Adirondack Mountains and is widely distributed. Mines have been opened in many places in the Southern and eastern Adirondacks in the counties of Essex, Warren, Washington and Saratoga and in St. Lawrence county in the northwestern Adirondacks. The graphite is almost entirely of the crystalline variety and occurs in flakes of various sizes or in rather coarse leaves. The size of the flakes roughly determines the amount of metamorphism the containing rocks have suffered. The rocks of St. Lawrence county being less metamorphosed than those on the opposite side of the mountains contain much smaller particles of graphite than the rocks in the vicinity of Lake George.

The history of the graphite industry of New York is similar to that of Pennsylvania in that it has been disastrous to many investors. Far more money has been lost than ever earned and there are instances of mines elaborately equipped with expensive mining and milling machinery that have been unable to produce graphite at a profit. Probably the majority of New York graphite companies have lost money on their investments. This has been due to the difficulties encountered in concentration mainly and not to the lack of the graphite.

According to Kemp* the graphite of the Eastern Adirondacks occurs in four kinds of rock: (1) pegmatite veins, (2) veinlets of graphite, (3) quartzites, and (4) crystalline limestones with associated gneissoid strata.

Deposits of the first class were formerly worked at Chilson Hill near Ticonderoga where mines were operated for many years with success, notwithstanding the pockety character of the material. The graphite occurred in large masses, in certain places practically pure, and at the present time it is possible to obtain unusually fine specimens of graphite rock on the old dumps. The graphite was associated with abundant quartz, calcite, pyroxene, hornblende, feldspar, mica, scapolite, apatite, spene, and other less common minerals.

The second class of deposits, where the graphite occurs in small veins, is represented at Split Rock, near Essex, on Lake Champlain and also on Chilson Hill. The graphite in coarse leaves fills fissures, some of which are several inches in width. These veins cut across the gneiss bands in all directions. The graphite is much purer than that of the pegmatites yet is apt to contain more quartz than is readily visible to the eye.

The graphite occurring in the quartzites is of greatest importance in New York and yields the greater portion of the entire production.

*Bull. No. 225, U. S. Geol. Survey, p. 512.

The mine of the Joseph Dixon Crucible Company at the town of Graphite is in rock of this kind. It has been continuously operated for more than 30 years and has the record for the greatest production of any graphite mine in the United States. The graphite occurs in flakes, rather evenly disseminated through a feldspathic quartzite. Small amounts of pyrite, mica, and apatite are present. The parallel arrangement of the graphite flakes and the slight elongation of the quartz grains produce a somewhat schistose appearance of the rock. The rock contains from 5% to 15% graphite. The graphite-bearing rock is a stratified bed with an average thickness of 10 to 12 feet but varying from 3 to 20 feet due to the intense squeezing to which it has been subjected. It outcrops near the top of a hill and dips gently into the hill. Overlying the graphite rock is a garnetiferous sillmanite-gneiss.

The ore is mined much as is coal, although few pillars are necessary. It is then taken to the mill nearby for concentration. The final cleaning of the flake is done at the refining mill at Ticonderoga.

The fourth type of graphite occurrence in New York is the disseminated graphite in lenticular beds of coarsely crystalline limestone. This type occurs in many places in the Algonkian strata of the Adirondacks but, so far as known, few deposits of this character have been worked for graphite. Phlogopite is usually associated with the graphite and would be separated only with difficulty. In some instances the graphite flakes with rather perfect hexagonal outlines attain a diameter of 1 inch.

NORTH CAROLINA.

Graphite is widely distributed in the crystalline rocks of North Carolina and deposits of some considerable promise have been found in Yancey, Mitchell, McDowell, Burke, Gaston, Lincoln, Rutherford, Cleveland, Alexander, Macon, Catawba, Wilkes, and Wake counties. The greater amount of the graphite occurs in graphitic schists, although, in certain places, it is present in pegmatite dikes. Many attempts have been made to mine it at various places and for several years the State produced about 100 tons annually.

"The most extensive operations have been carried on near Graphiteville, McDowell county, near the eastern slope of the Blue Ridge. The ore is largely amorphous and occurs as a zone in the metamorphic mica schists in which the graphitic members are developed to a width of about 300 feet, and in a general way pretty uniform in character for several miles toward the east. The zone is built in such a way that there is a series of strata within the prevalent rocks at that locality—hard mica schist—in which a part of the mica has been substituted by amorphous and microcrystalline

graphite, a mineralogical phenomenon frequently observed in this and other countries and for which the name 'graphitic schists' is generally adopted. The contents of graphite of these strata is, as a rule, very low, and has been found in hundreds of samples running from 3½ to 9 per cent., but in some parts of the series 18 per cent., and even as high as 27 per cent. The principal impurities in this lean graphitic ore are mica, siliceous slate, quartz, pyrites of iron and their product of decomposition, hydrous sesquioxide of iron."*

OHIO.

In 1904 some graphite was reported to have been mined about 8 miles northeast of New Philadelphia, Ohio, by the Goshen Coal Mining Company. Although nothing is definitely known concerning this occurrence it is probable that the so-called "graphite" is simply a carbonaceous shale mined for use in the manufacture of paint.

OREGON.

So far as known, graphite has never been worked in Oregon, but deposits of it are said to occur near Baker City.

PENNSYLVANIA.

The full descriptions of the graphite deposits of Pennsylvania are given on later pages.

RHODE ISLAND.

Graphite occurs in several places in Rhode Island and in several different forms and has been intermittently worked for many years. The graphite is all amorphous and is used for paint, foundry facings, and polishes. No attempt is made to free the graphite from its associated impurities, the rock being ground, bolted and sacked for shipment. It occurs in the Coal Measures which have undergone sufficient metamorphism to transform a considerable portion of the carbonaceous matter of the original shales into graphite. Associated coal beds in the vicinity of Providence have been converted into an impure form of graphite or graphitic anthracite than can only be burned with difficulty. The graphitic carbon in the Cranston material varies from 25% to 40%.

The following descriptions† of the two principal localities are by Prof. C. W. Brown of Brown University.

*Manuf. Rec., Vol. 54, p. 138, 1909.
†Min. Resources for 1908. U. S. Geol. Survey, Pt. II, pp. 731-732, 1909.

PROVIDENCE COUNTY.

"*Cranston mines.*—The largest of the Rhode Island mines is at Fenner Ledge, in Cranston, a suburb of Providence, and is typical of the mode of occurrence in the western portion of the Narragansett basin. This locality has in the past been worked by a number of companies, among others the Rhode Island Graphite Company. A stock company, capitalized at $50,000 was formed in 1898 by J. Mason Gross. The venture, however, was not a success, and for the last two years the property has been worked on a small scale by Mr. Fenner.

"The section at Fenner Ledge, as exposed from west to east on a quarried face, is as follows:

SECTION AT FENNER LEDGE, CRANSTON, R. I.

	Feet.
Slightly sheared coarse sandy shale, with occasional pebbly beds	60
Darker, more carbonaceous shale, speckled with glistening plates of ottrelite	75
Graphitic shale, much crumpled and possibly faulty	20
Sandy shale	25
Highly contorted graphitic shales showing lustrous graphite on the sheared surfaces, with more clayey material between; some small quartz and pyrite veins (this is the principal portion which has been worked for graphite	30
Somewhat carbonaceous shales, with a small bed which is quite graphitic	100+

"Just south of the cliff section described above, at the openings formerly worked by the Rhode Island Graphite Company, the most graphitic portions show close folding with westerly overturning and a gentle northerly pitch. The worked bed is 12 to 14 feet wide, and pinches out upward. The strike is north-northeast, with an easterly dip of 50°. A drift some 30 feet high has been carried along this bed for about 100 feet. As much as 15 tons was taken from this property per diem with a working force of 12 men. In all, about 30,000 tons must have been taken out during the intermittent operations of this property for the last ten years. The plant, which is now abandoned, consisted of a 50-horse power hoisting engine, sheds for crushing, pulverizing, drying, bolting through silk or brass mesh (from 160 to 220 to the inch), and barreling. The product was shipped to eastern and western firms for foundry facings.

"The present operations are confined to the open quarry face, whose detailed section is given above, and about 300 tons of crude material have been shipped in the last two years, at an average sell-

ing price of $6 per ton. The material is excavated cheaply by hand drilling and blasting, and shipments are made to the Springfield Facing Company, Springfield, Mass.; to Cincinnati; Detroit; Hamilton, Ontario; New York City, and to New Jersey firms.

NEWPORT COUNTY.

"*Tiverton quarry.*—The graphitic schist worked between Tiverton and Little Compton is exposed in an open cut on the beach. It is exposed for a length of 70 feet and a width of 25 feet. Since it is located at tidewater, any downward development will have to take this factor into consideration. Henry Sisson has worked this occurence on a lease for the last ten years, and in that period has extracted at a low cost per ton about 200 tons. After grinding by the Springfield Facing Company, it is sold for paint at about $100 per ton. Recently some contracts for painting bridges and gasometers with this paint have been made. The graphite at this locality appears to be more unctuous to the touch than at other places. There has been more shearing and faulting, but less contortion, than to the westward. Underneath there are also some occurrences of crude hematite and larger quartz veins than at Cranston.

"Other localities with shafts were filled with water, and no data could be secured.

"All the evidence shows that the graphite represents an original carbonaceous constituent of these rocks, which has been converted into its present form by heat and pressure. The most highly graphitic portions of the graphite-bearing formations are the softest and the most crumpled."

SOUTH CAROLINA.

Graphitic slates occur in several places in the western part of the State, particularly in the counties of Cherokee, Oconee, and Anderson. The graphite runs as high as 3 per cent. in places. Along the Rocky River valley in Anderson county these graphitic slates are said to have been worked to a limited extent in the eighties.

SOUTH DAKOTA.

"Graphitic slates are abundant in many parts of the (Black) Hills and in not a few places the percentage of graphite is sufficiently high to arouse some interest in the economic possibilities of the deposits. Considerable prospecting has been done in the Central Hills, particularly near Custer and Rockford. Recently (1902) sixteen car loads of the mineral were ground at the Mineral Paint works in Custer and shipped to Aurora, Illinois, for final preparation for market."*

*O'Harra: Bull. No. 3, S. Dak. Geol. Survey, p. 72.

At Black Eagle, Pennington county, a deposit of graphite was prospected late in 1907, but data concerning it are not available.

*TEXAS.**

"Graphite-bearing schists are widely distributed throughout the pre-Cambrian series, though the content of graphite is very variable. In most instances the graphite schists are associated with limestone or marble, a natural occurence since carbonaceous shales are often associated with limestone strata. Often these schists can be traced for long distances.

"Graphite-bearing schists were noted at many localities, but since only one of these is as yet considered of importance a description of the occurrence at this locality will serve as a measure of those left undescribed; for, it may be said in general, that it would not be advisable to spend money upon prospecting or testing at other localities until the deposit in question is proved a commercial success. If any exception be made to this statement it would be that perhaps certain beds carry sufficient graphite to be of value as a paint pigment, in the industrial manufacture of which a very impure graphite can be used.

"The locality which has received and warranted the most attention is 1 7-8 miles due south of Lone Grove, is approximately 1,500 feet west of Little Llano River, and about 800 feet north of the Houston and Texas Central Railroad. The property is controled by R. H. Downman, of New Orleans.

"The graphite occurs in graphitic schists associated in this vicinity with considerable limestone. Granite and pegmatite instrusions have locally disrupted the beds, and at a first glance the impression might be formed that pegmatite had introduced the graphite. A careful examination of the graphite bunches in the pegmatite shows, however, that they represent broken fragments of schist. A specimen was polished and etched with hydrochloric acid, which in dissolving out the calcite contained between the laminae of the schist fragments showed clearly the schistose nature of the graphite.

"The graphite-bearing schists can be traced with interruptions for half a mile northwestward from a point a little west of the railroad bridge, through the present workings, to a point where the series disappears beneath overlying Cambrian sandstones. Graphite is also reported across the river to the south in the same trend.

"The deposit has been prospected by a shaft with underground workings and by a number of surface cuts, four or more, over a distance of about 500 feet.

*Paige, S., Min. Res., 1909, U. S. Geol. Survey, Pa. II, pp. 830-832.

"A private report made in 1902 by William Young Westervelt and furnished by the courtesy of Mr. R. H. Downman contains much interesting data on this property, and the following notes are copied or abstracted from it.

"An average sample taken over the length of a 72-foot prospect cut showed a carbon content of 11.45 per cent.

"A number of tests were made with the following results:

"A general sample was made up of all the samples secured underground and crushed to pass a 10-mesh sieve. It was assayed and found to contain 14.50 per cent. graphite * * * Further tests indicate that ore containing 14.50 per cent. carbon (the assay of the made-up general sample) will yield from 1 to 4 per cent. of its weight of flaked graphite* containing from 56 to 40 per cent. carbon whose impurities contain less than 2 per cent. each of iron (Fe) and lime (CaO) the most common of the objectionable impurities for crucible manufacture. Also * * * that fine graphite could be produced amounting to from 27 to 28 per cent. of the original ore and containing from 29.75 to 25.80 per cent. pure graphite, the total recovery of graphite in the form of flake and fines being 60 to 61 per cent. of the total graphite in the original sample.

"Other tests on specially selected samples were made, but need not be presented here.

"Much of the territory included in this property has not been adequately tested by surface cuts, and it is believed that possibilities exist for the successful establishment of a graphite industry at this point.

"South of Llano, about 2 miles, graphite schists trending in a northwest-southeast direction toward Sharp Mountain may be observed. In this vicinity, perhaps, with the exception of the property already described, exists the most favorable opportunity to prospect, though graphite schists occur at many localities throughout the region. It must be borne in mind, however, when making an estimate of the graphite content of a given band of schist that appearances are very deceptive, a very little graphite making a very striking showing."

UTAH.†

During the summer of 1909 the Humber Mining Company of Salt Lake City opened a mine on Threemile Creek near Brigham City, Boxelder county, Utah, and shipped a small tonnage for experimental purposes. The deposit is said to have been first discovered by prospectors in 1864. The so-called graphite occurs in a schist of pre-Cambrian age associated with other schists slates, graywackes, con-

*Too large to pass a 60-mesh sieve.
†Gale, H. S., Bul. No. 430, U. S. Geol. Survey, pp. 639-640.

glomerates, and quartzites, all more or less sheared and contorted. "The carbonaceous beds exposed in the shallow prospects appear to be at least 15 or 20 feet in thickness and as they evidently represent an original stratum of the sedimentary series it is quite probable that they may prove fairly persistent both horizontally and in depth throughout the area in which the outcrops occur. The carbonaceous schist shows a black lustrous polish resembling that of graphite, especially in joints or on the foliation of the rock. When pulverized, however, the substance lacks the smooth, greasy feeling of pure graphite, but much of the material selected as most promising for commercial use appears to be free from coarse sand and grit."

Analyses of the rock gave from 3.48 to 5.59 per cent. of fixed carbon but all this burned off in the flame of an ordinary Bunsen lamp without the use of a blast, showing it to be more of the nature of impure coal than of graphite. The material may have some value in the manufacture of paints but it not applicable to most of the purposes for which graphite is used.

VERMONT.

Graphite occurs in the crystalline rocks of Vermont in many places, particularly at Brandon, Newbury, Swanton Falls, Pittsford, Norwich, Hancock and Huntington. No information is available concerning any graphite mines in that state, but there is little doubt but that prospect mines have been opened there in the past as in all the other New England states.

VIRGINIA.

"Graphite is found in Virginia at a number of localities in the Piedmont region east of the Blue Ridge.* Near Somerset station in Orange county on the Somers place a large exposure of graphitic schist occurs, and at the same place much graphite is reported mixed with pyrite in a pyrite vein. In Louisa county, near Green Spring, specimens of graphite of considerable purity are found. Good specimens of the mineral have also been obtained on the road from Drakes Branch to Saxe in Charlotte county. It is reported from near Jefferson post office in Powhatan county.

"A graphite mine was opened some years ago about 2 miles west of Buck Mountain in the northern part of Albemarle county by the Naylor-Bruce Graphite Co. The mine has been idle for several years, and the openings were so covered at the time of the writer's visit in April, 1911, that very little could be seen of the geology of the deposit.

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*Watson, Thomas L., Mineral Resources of Virginia, 1907, pp. 188-190. Published by Jamestown Exposition Commission.

The mine is on a northeast hillside on the farm of W. A. Naylor. A lower pit only 20 feet above the creek level is about 10 by 10 feet and 15 feet deep and was water filled. The rock exposed near the pit is a mottled green and gray rock of somewhat gneissic texture, which is stated by T. L. Watson to be a pyroxene syenite. The principal working is a short distance higher up in the hillside and consists of an open pit 40 by 30 feet and 12 feet deep, and of a shallow shaft. A small shaft house has been erected. The principal wall rock is the pyroxene syenite which strikes N. 60° E. and dips about 80° SE. This syenite is intruded by diabase dikes, one dike at this pit being 14 inches wide, and by a 3-inch dike of pegmatite much weathered but showing feldspar crystals up to three-fourths of an inch and quartz crystals up to one-half inch across.

"Graphite is exposed only on the south wall of the open pit where the rocks are much weathered. Here there is a single vein cutting the pyroxene syenite and varying from 1 to 2 inches across. This sends off into the syenite numerous short branches up to three-fourths of an inch across. The vein is composed largely of graphite with little or no gangue material. The graphite is in part earthy in texture, but in other places is crystalline with a well-developed fibrous structure. Some hand specimens forwarded to the Survey show some of the graphite fibers oriented at right angles to the sharply defined walls of the vein, but in other specimens they curve through angles of over 90°, possibly as a result of movement along the vein. In some places the fibres even lie parallel to the vein walls. The property is said to have yielded single blocks of graphite weighing several hundred pounds. An analysis by Froehling and Robertson, of Richmond, gave 76.28 per cent. of graphitic carbon.

"In general the exposures were too poor to reveal much in regard to the origin or probable extent of the deposit."*

WASHINGTON.

Graphite was mined in the State of Washington about 10 years ago by the Shelbyville Consolidated Mining Company, but the project was unsuccessful.

WISCONSIN.

Graphite has been mined within recent years near Junction City, Portage county, by two companies. The principal company is the Wisconsin Graphite Company whose mill is located at Stevens Point. The graphite is amorphous and is mainly used in the manufacture of paint, lubricants and paste. Some specimens have been reported to contain 74% carbon. It is similar to the Baraga graphite of Michigan.

*Bastin, E. S.: Min. Res., 1910, U. S. Geol. Survey, Pt. II, pp. 908-909.

WYOMING.

Graphite has been found in many places in the State, but in only a few places has systematic development work been done to prove the value of the deposits. The graphite is of the amorphous variety.

In Albany county, 27 miles northeast of Laramie, there is a district known as "Plumbago Canyon," where there is much graphite. The deposit has been traced to the northeast as far as Hallac Canyon, a distance of about 20 miles. About 40 years ago a few shallow shafts and tunnels were made but the deposit did not seem to warrant the equipment of a concentrating plant and the project was abandoned. One analysis showed 51.35 per cent. of graphite.

Graphite also occurs in many places in the hills around Haystack Peak, Laramie county.* The graphite occurs as a constituent of sedimentary pre-Cambrian muscovite schists which have been intruded by granite and pegmatite. The carbonaceous materials of the schists have been metamorphosed to graphite by the igneous rocks.

As seen under the microscope the graphite schists contain much finely disseminated graphite associated with quartz, tourmaline, a little biotite, muscovite, and feldspar. Some specimens contain as much as 16 per cent. of carbonaceous matter, not all of which is graphite, however. The graphite particles are so small, from 0.04 to 0.15 mm., that it is doubtful whether they could be separated economically from the associated minerals.

Graphite of good quality and large amount is also said to occur near Miners' Delight in Fremont county.

CHAPTER VII.

ARTIFICIAL GRAPHITE.

No discussion of graphite is complete without an account of artificial graphite which has been manufactured at Niagara Falls by the International Acheson Graphite Co. since 1897. With the exception of 1902 and 1909 when the output was slightly lower than the preceding years there has been a steady and rapid increase in the production of artificial graphite by this company and the product both in quantity and value, but especially the latter, has greatly exceeded the annual production of natural graphite in the United States for several years. Notwithstanding the great production of the artificial graphite the market for the natural product does not seem to have changed materially on this account.

*Ball, S. H.; U. S. Geol. Survey, Bull. No. 315, pp. 426-428.

In 1896 Dr. Edward G. Acheson obtained a patent for a process of manufacturing graphite in the electric furnace and the following year placed the product on the market. The process which has been slightly changed from time to time is a simple one and consists merely of the heating to high temperature in the electric furnace of a mixture of some form of amorphous carbon and certain other ingredients that might be regarded as impurities. By experiment it has been found that the most satisfactory results are obtained by taking petroleum coke or the culm of anthracite coal, of which there are such great quantities about many of the collieries in the anthracite region, and smaller amounts of quartz sand and saw dust. The anthracite culm which contains about 80% fixed carbon is mixed with enough of the other constituents to lower the percentage of fixed carbon of the mixture to about 60%. This mixture is put in a long trough-like furnace in which a carbon rod is placed to make electrical connection between the terminals because of the low electrical conductivity of the amorphous coal. The temperature is raised to approximately 7500° F. when the impurities volatilize and the amorphous carbon is converted into graphite.

In the process of converting the carbon into its crystalline form, Dr. Acheson believes that carbides, principally the crystalline silicon carbide (carborundum) is first formed which is later decomposed forming graphite psuedomorphs. This explanation has been generally accepted in lieu of any better one, but is disputed by certain investigators. The graphite produced in this way is essentially pure carbon, many analyses showing 99.8+% C. while practically all the artificial graphite contain more than 99% C.

The uses to which artificial carbon has been put are varied and new uses are being continually found. Perhaps of greatest importance is its use for electrodes for electrochemical and electrometallurgical purposes. In electrodes the best results are obtained by using practically pure graphite and the company plans to have their electrodes contain 99.5% graphitic carbon. Most of the electrades are made by mixing the amorphous carbon and other materials together and shaping them in the desired form in molds or by forcing the mixture through a die under heavy pressure. The elements, otherthan carbon, are volatilized in the electric furnace and the amorphous carbon converted into graphite, the article retaining its original form. After graphitization the electrodes can be cut, machined, or threaded as desired.

Much of the artificial graphite is marketed in the dry powdered form for various uses, such as dry cell fillers, paint pigments, lead pencils, polishes, coating for gunpowder, for electroplating, etc. For most of these purposes it seems to be well adapted although there is difference of opinion regarding its value for other than electrical pur-

poses in comparison with natural graphite. For different uses it is prepared in various degrees of fineness with slightly different physical and chemical properties.

Recently the company has been extending its use as a lubricant through a new discovery of Dr. Acheson. At first it was found difficult to use their product as a lubricant because of the particles of graphite settling out of the liquid with which it was mixed. In 1906 he succeeded in reducing the particles of artificial graphite to such a fine state of division that they remain in suspension in either oil or water for an almost indefinite length of time. To produce such results the graphite particles are disintegrated in an impact mill until fine enough to pass through a sieve containing 40,000 meshes per square inch. The disintegration is carried still further by mixing with the graphite from 3% to 6% by weight of tannin in solution and a small amount of ammonia. It is claimed that this later treatment reduces the size of the particles to about 1-1000 of the original size or essentially to the molecular condition. This material remains in suspension in oil or water and is marketed under the trade name of "Deflocculated Graphite."

PRODUCTION OF ARTIFICIAL GRAPHITE 1897-1910.

Year.	Quantity, pounds.	Value.	Price per pound.
			Cents.
1897,	162,382	$10,149	6.25
1898,	185,647	11,603	6.25
1899,	405,870	32,475	8.00
1900,	860,750	68,860	8.00
1901,	2,500,000	119,000	4.76
1902,	2,358,828	110,700	4.69
1903,	2,620,000	178,670	6.82
1904,	3,248,000	217,790	6.70
1905,	4,595,550	313,980	6.38
1906,	*5,074,757	337,204	6.64
1907,	*6,590,000	481,239	7.30
1908,	7,385,511	502,667	6.80
1909,	*6,664,017	480,000	7.20
1910,	13,149,100	945,000	7.20
1911,	10,144,000	664,000	6.54

*The figures for 1906, 1907 and 1909, taken from statistical reports of the U. S. Geological Survey, differ slightly from those given in a recent publication of the International Acheson Graphite Company. The value and price per pound are not given in the latter article, so it seems best to retain the figures of the Geological survey.

PART 2

GRAPHITE DEPOSITS OF PENNSYLVANIA

CHAPTER VIII.

HISTORY OF GRAPHITE MINING IN PENNSYLVANIA.

Graphite was probably first worked in Pennsylvania near Trevose in Bucks county, but the exact date and the extent of the operations are not known. Rogers in his Fourth Annual Report* states that "rather more than a mile south of the Buck Tavern, on the banks of the north branch of the Paquasin (Poquessing) Creek, there is a locality where Plumbago, or black lead, was formerly worked, but the place is abandoned, and the pit filled up." Again, in his Final Report† published in 1858, he says "Near the Buck Tavern on the New Hope Turnpike, there is an old mine of plumbago on the farm of Isaac Hogeland. A tradition states that black-lead was procured here more than a hundred years ago. After lying long neglected, the mine was recently reopened, but it is again in a state of dilapidation, and no accurate observations respecting the vein or bed are at present practicable."

A graphite mine is also said to have been worked for a short time at an early date about ¾ mile east of Langhorne, Bucks county.

The next place to be worked for graphite seems to have been in the region of Pughtown, Chester County. Rogers in his Final Report‡ describes the deposit briefly. "Near the junction of Beaver Creek with French Creek, or a short distance to the S. W. of Pughtown, there is a vein of impure plumbago on the farm of Jesse Hawley. It occurs between beds of gneiss, is about 3 feet in thickness, and dips with the strata to the S. E. about 45°. The plumbago is pulverulent, and mixed somewhat with foreign matters, especially oxide of iron, oxide of manganese, and some of the minerals of the gneiss in a state of disintegration. The excavation exposing it is a very superficial one, being merely a drift, of the length of a few fathoms, penetrating the vein at the water-level. After being mined, the material is broken, screened and washed, when it is packed and sent to West Chester, there to be converted into fire-proof mineral paint for railroad cars, houses, barns, and other structures. The paint is prepared dry, and also ground in oil. It has been found very useful in resisting atmospheric exposure, though it has been employed as yet to a very limited extent." This mine was near the present plant of the Eynon-Just Company of Coventryville and in the same area of graphite-bearing rock.

At about the same time, or perhaps earlier, a mine was opened one mile east of Vera Cruz Station, Lehigh county, which was first

*Fourth An. Rep. Geol. Surv. of State of Pa., p. 14, 1840.
†Geol. of Pa. Vol. I, p. 81, 1858.
‡Geol. of Pa., Vol. II, p. 709, 1858.

called a gold mine but later operated for graphite. The pyrite and marcasite were either confused for gold or possibly contained small values in gold as is commonly the case.

In the late '70's graphite seems to have been dug at two places near Boyertown; close to "Dr. Funk's fish dam," about one-half mile west of town, as designated on the topographic map of that section, published by the Second Pennsylvania Geological Survey in 1883, and also on the farm of J. Bechtel about one mile west of town. These were probably mere prospect holes at that time although at a later date the graphite deposit located one mile from town was rather extensively worked.

The Pickering Creek graphite deposits, which, at present, are the most important ones in the State, were also first worked in the late '70's. The Phoenix mine now owned and operated by Pettinos Bros. is said to have been the first one opened. Somewhat later the graphite on the adjoining property was worked by the Pennsylvania Graphite Mining and Manufacturing Company, which later became the Pennsylvania Graphite Company. In 1880 this was the only operating plant. It employed from 32 to 40 men and produced 440 tons in that year valued at $24,000, according to the statistics given in the Tenth Census reports.

In the "Mineral Resources" of the U. S. Geological Survey for 1882 the following statements occur. "Numerous attempts have been made to work the similar deposits of Pennsylvania and New Jersey, with only partial success. The parties interested in these attempts are: The Pennsylvania Plumbago Co., the Eagle Plumbago Co., and the Phoenix Plumbago Co., all of which have worked deposits in the Pickering Valley, Pennsylvania."

In Persifor Frazer's "Geology of Chester County," submitted in 1882 and published in 1883, the following statements are given (p. 232). "The Chester Springs Plumbago Mining and Manufacturing Company's mine is situated in the eastern quarter of the township (West Pikeland), a quarter of a mile due west of the Mt. Vernon school-house, just a mile due southeast of the railroad bridge over Pickering Creek. All that can be said about this is that the company are prospecting with a reasonable hope of finding a workable vein." This was probably on the property of the present Federal Carbon Company.

No production is given for Pennsylvania between the years of 1880 and 1889 in the annual reports on the Mineral Resources of the United States, published by the U. S. Geological Survey. The 1886 report (p. 686) states that during that year considerable development was done by the Plumbago Mining Co. in their mine at Byers but no production is reported.

In 1889 according to the Eleventh Census Report Pennsylvania produced 2,721 short tons of graphite, valued at $16,752. During the same time the graphite companies expended $16,979. The excess of expenditure above value of production was due to development work that was being carried on during that time.

In 1890 Pennsylvania produced a small amount of graphite. The report of the Mineral Resources for 1889-1890 states that "In 1890 the product consisted of 500 tons from Pennsylvania and New Jersey marketed in the pulverized form for $20,500."

The report on the Mineral Resources for 1891 states that "no work of any consequence was done upon the (graphite) properties in Pennsylvania...........though the owners report the expectation of resuming operations at an early date."

A production of 100,000 lbs. of graphite was mined in Berks county in 1892, according to "Mineral Resources" for that year. This probably came entirely from the Boyertown mine.

No production is reported in Mineral Resources for 1893, 1894, 1895 or 1896, but Pettinos Bros. operated during 1895 and 1896, producing from 3 to 4 tons of concentrates per day. Some production, from Byers, is reported for 1897, but no figures are given. During the same year the Philadelphia Graphite Co. opened a mine one mile east of Chester Springs, according to "Mineral Industry." Also in 1897 the Penn Graphite Co. opened up the Riley mine that had been idle for many years about three-fourths mile south of Mertztown, Berks county, and proceeded to operate it on a large scale.*

The following statements are made in the Mineral Resources for 1898 (p. 716). "Outside of the increased production in 1898, the interesting feature was the transfer of the mines in Chester county, Pennsylvania, formerly owned by the Penn Plumbago Company, to a new corporation, known as the Standard Graphite Company. This company was engaged in sinking a new shaft and in placing new machinery at the close of 1898, and expected to be shipping early in 1899. The company expects to develop a considerable export trade."

From the same source an increased production is reported from Chester county for that year.

According to Mineral Industry for 1898, graphite was produced that year by the Philadelphia Graphite Co. and by Pettinos Bros.

No figures are available for the production of graphite in Pennsylvania during 1899. Early in the year the works of Pettinos Bros. at Byers were burned. The Penn Graphite Co. which had reopened the mine near Mertztown in 1897, became productive and "in July, 1899, was producing at the rate of 2 tons of graphite per day.

*"Mineral Industry," 1899, p. 350.

Three-fourths of the product was flake graphite, the remaining fourth was of a lower grade, and was utilized in the manufacture of graphite paint."*

The same year "the Boyertown Graphite Co. reopened the old graphite mine, a mile west of Boyertown, Berks county, and erected a mill for the separation of the graphite from the gangue material."†

During 1900 there was an increased production of graphite in the State. "The companies in operation in 1900 were the Philadelphia Graphite Co. and the Federal Graphite Co. at Chester Springs, the Penn Graphite Co. near Mertztown, and the Boyertown Graphite Co. at Boyertown."‡ The graphite works at Byers were destroyed by fire in 1900.§

The only graphite mine reporting a production in 1901 was the Philadelphia Graphite Mine at Chester Springs. The same company and its successor, the New Philadelphia Graphite Company, were the principal producers during 1902. That year the Federal Graphite Co. equipped its plant with a magnetic concentrator planning to clean the graphite concentrates with hydrochloric acid in the attempt to produce a higher grade product.

In the same year Husband's Graphite Company was organized to work a deposit about 1 mile north of Hallman Station on the Pickering Valley Railroad.

Early in 1903 the mill of the Federal Graphite Company burned. It was at once rebuilt but not completed until late in the Fall. The Philadelphia Graphite Company suspended work for part of the year in order to develop its mine.

In April, 1903, The Pennsylvania Graphite Company was incorporated with a capital of $100,000.

There is said|| to have been an increased production of graphite in Pennsylvania in 1904, but no mention made of amount or the names of the producing companies.

In 1905 the principal producers were the New Philadelphia Graphite Company, which was the successor of the Philadelphia Graphite Company, and the Federal Graphite Company. The former spent the larger part of the year in reconstructing its mill while the latter closed down in July.

During the same year the Columbia Graphite Company was organized and purchased the property of the Boyertown Graphite Company and made plans to re-open it. The United States Graphite Company was organized and leased the mine of the Pennsylvania Graphite Company at Byers and began the construction of a large finishing mill at the same place.

*"Mineral Industry," 1899, p. 350.
†"Mineral Industry," 1899, p. 350.
‡"Mineral Industry," 1900, p. 379.
§"Mineral Industry," 1901, p. 369.
||"Mineral Resources," 1904.

The National Graphite Company, the successor of the National Mining Company, was organized to work a deposit near Anselma and the Continental Graphite Company acquired a property at Byers soon after acquired by the United States Graphite Company. The Crucible Flake Graphite Company was organized in the same year to work a deposit near Chester Springs.

The yield for Pennsylvania during 1905 according to the "Mineral Industry,"* was about 445,000 pounds.

During 1906 there was much activity in the graphite industry of the State. The New Philadelphia Company, the National Graphite Company, and the United States Graphite Company reported productions during the year. The Federal Graphite Company and the National Graphite Company changed hands. The Columbia Graphite Company resumed operations at their mine near Boyertown in November, 1906, after having been closed for 18 months. The Continental Graphite Company, the Sterling Graphite Company, and the Parker Graphite Company, new companies, began the construction of mills, the former at Byers, the latter two near Chester Springs.

During 1907 the producing companies were the Chester Graphite Company, the Sterling Graphite Company, the United States Graphite Company, and the National Graphite Company. The latter two ceased operations during the year. The first named company was formed during the year and leased the property of the Keystone Graphite Company, which company had succeeded the New Philadelphia Company.

The production amounted to 1,374,000 lbs., valued at $51,960.

Three firms reported production during 1908. The Federal Graphite Company remodeled its mill.

In 1908 an injunction was issued against the United States Graphite Company, restraining it from using the name on account of the existence of an earlier company by the same name located at Saginaw, Michigan. The name was accordingly changed to the Imperial Graphite Company.

In July, 1908, the American Flake Graphite Company was incorporated in Camden, N. J., with a capital of $50,000 to work a deposit on Phoenix Hill, about 3 miles southwest of Phoenixville.

The Pennsylvania production in 1908 was 356,000 lbs., valued at $16,740, or 1,318,000 pounds less in quantity and $35,220 less in value than in 1907.

During 1909 the chief producers were the Pennsylvania Graphite Company, the Chester Graphite Company, and the Sterling Graphite Company. The United States Graphite Company and Continental Graphite Company discontinued operations. The Acme Graphite

*"Mineral Industry," 1905, p. 311.

Company was organized and took over the latter company. The Federal Graphite Company was organized under the name of the Federal Carbon Company.

Production during 1909 was 1,202,416 lbs., valued at $58,006.

In 1910 the State produced 1,861,000 lbs. of graphite, valued at $87,840. The producing firms were the Chester Graphite Company, which ceased to operate toward the close of the year and gave up its lease of the property, the American Flake Graphite Company, the Acme Graphite Company and Pettinos Bros. The Sterling Graphite Company was succeeded by the Rock Graphite Mining and Manufacturing Company.

During 1911 there was little activity in the graphite industry in Pennsylvania and part of the time no mines have been in operation. The American Flake Graphite Company operated in the early months of the year while the only other operating companies were Pettinos Bros. and the Eynon-Just Company which began working the property formerly belonging to the Imperial Graphite Company near Coventryville.

CHAPTER IX.

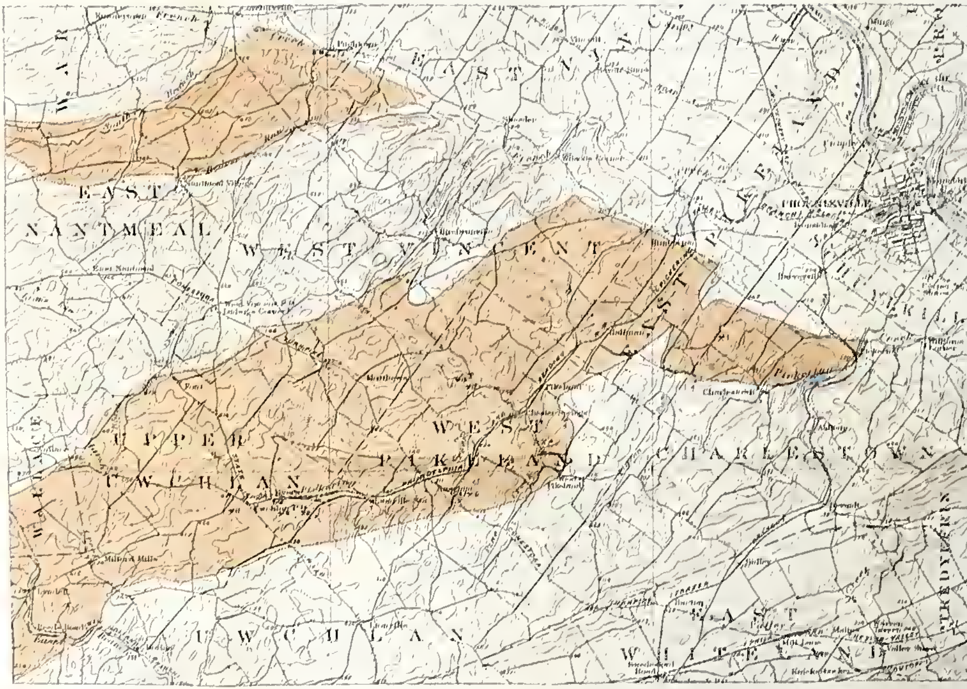
GEOLOGY.

LOCATION OF DEPOSITS.

The graphite deposits of Pennsylvania are limited to the greatly metamorphosed pre-Cambrian and early Paleozoic rocks forming the Piedmont Plateau of the southeastern corner of the State. Graphite has been mined in the four counties of Chester, Berks, Bucks and Lehigh and is present as an occasional mineral in several other counties.

The most important districts lie in the valley of Pickering and French creeks, Chester county forming part of the Phoenixville quadrangle of the U. S. Geological Survey. In Pickering Valley, graphite has been mined in many places between Kimberton and Byers, a distance of about 8 miles and for many years that region has been the center of the graphite industry of the State. The second locality in Chester county is in the vicinity of Pughtown in the valley of French Creek where some of the earliest mining was first done and where, at present, one mine is in active operation.

Berks county is of secondary importance. Several mines and many prospects have been worked in the eastern portion of the county, all of which are included in the Boyertown quadrangle of the U. S. Geological Survey. At the present time no mines are in



NOTE: The outlines of the Graphite (Pickering) Gneiss have been taken mainly from a manuscript geologic map prepared by F. Bascom. Small areas of Franklin Limestone, Baltimore Gneiss, and dikes of Gabbros, Serpentines, and Diabase are not represented.

GRAPHITE GNEISS AREAS OF PHOENIXVILLE QUADRANGLE, CHESTER COUNTY, SHOWING LOCATION OF GRAPHITE MINES

MINES AND MILLS

1. American Flake Graphite Co.
2. Girard Graphite Co.
3. Federal Carbon Co.
4. Chester Graphite Co.
5. Consolidated Graphite Co.
6. Anselma Graphite Co.
7. Pickering Valley Graphite Co.
8. Pettinos Brothers.
9. Pennsylvania Graphite Co.
10. Mill of Eynon-Just Graphite Co.
11. Acme Graphite Co.
12. Rock Graphite Mining & Mfg. Co.
13. Crucible Flake Graphite Co.
14. Eynon-Just Graphite Co.

operation in Berks county, but, in the past, extensive mining has been carried on in the vicinity of Boyertown and near Longswamp or Mertztown.

Bucks county is the seat of the earliest graphite mining within the State, so far as known. A mine near the present station of Trevose was early worked but so long since abandoned that little information concerning it is now available.

At different times some graphite mining has been done in the eastern part of Lehigh county in the vicinity of Vera Cruz Station and Emaus, but these mines and prospects have been abandoned for many years. Some of the deposits are, however, of sufficient importance to justify investigation.

Besides the above-mentioned counties where graphite has actually been mined, it occurs in several places in other counties. In Northampton county graphite is found near Easton and about 3 miles north of Bethlehem. It is reported at one point in Philadelphia county. Also there are many other localities in Chester and Berks counties where graphite occurs besides those places where it has been mined.

Although the material is of no value it is of interest to know that graphite occurs on the slickensided surfaces of the cement rock in many places in the belt of cement rocks of Northampton and Lehigh counties. The workable slates of adjoining areas also have had part of their originally contained amorphous carbonaceous materials converted into graphite. The explanation of these occurrences is the intense dynamic metamorphism which these rocks have locally undergone.

DESCRIPTION OF THE GRAPHITE DEPOSITS.

The graphite of Pennsylvania occurs in rocks that have suffered great metamorphism either regional or contact or both. These rocks belong mainly to two classes, marbles and granitic gneisses. Graphite occurs less abundantly in some gabbros, basic gneisses, slates and sandstones.

The marble in which graphite is found is a coarsely crystalline calcareous rock that outcrops in many places in the State. It was called "sparry limestone" by the Second Pennsylvania Geological Survey. In several places in Northampton, Bucks and Chester counties it has been quarried and burned for lime in the past, but at present is not being utilized. It is well developed in the vicinity of Easton where it contains much tremolite, graphite and phlogopite; about 3 miles north of Bethlehem where it carries much graphite; at Van Artsdalen's quarry about 3 miles west of Langhorne where it contains graphite, feldspars, scapolite, titanite, phlogopite, apatite, and about 20 other minerals; at the Bittenbender iron mine near Seisholtzville, Berks county, where it occurs in conjunction with ex-

tensive magnetite deposits and contains many basic silicate minerals and graphite; and in several places in the Pickering Valley, Chester county, where it contains much graphite, feldspar, epidote, pyroxene, and other silicates.

This limestone is very coarsely grained, in certain places the individual particles being as much as an inch in diameter. Graphite, or graphite and phlogopite, in small flakes about one-eighth inch in diameter are rather evenly distributed throughout the rock but with no regularity or apparent order of arrangement where other minerals are absent. But, in certain places, the marble is very impure and various silicates, particularly the basic ones, are present and they are arranged in approximately spherical or globular segregations varying from a few inches to several feet in diameter. The graphite associated with such segregations is usually in much larger flakes, in places as much as one-half inch in diameter. Many of the flakes show distinct hexagonal outlines.

No bedding planes are to be seen in the marble outcropping in this State consequently the dip, strike, and thickness of the formation are not determinable. The limited outcrops, however, seem to indicate a thickness not exceeding a few hundred feet.

No attempt has been made to separate graphite from this coarsely crystalline marble in Pennsylvania and probably never will be.

In the Trenton folio of the U. S. Geological Survey Miss F. Bascom has designated this formation the Franklin limestone, correlating it with the pre-Cambrian formation of that name that contains the valuable zinc deposits of Franklin Furnace, New Jersey. Certainly there are excellent reasons for doing so as specimens from various localities in Pennsylvania could not be distinguished from similar materials quarried so extensively in the Franklin Furnace region. Also the geologic occurrence of the rock in the two districts is similar.

The other common occurrence of graphite in Pennsylvania is in the gneisses. In mapping the crystalline rocks of the Trenton quadrangle, Miss Bascom included the graphite-bearing gneisses in the Baltimore Gneiss, but in her map of the Phoenixvile quadrangle, that will later be published as part of a folio by the U. S. Geological Survey, she separates the graphitic gneisses from the non-graphitic gneisses of the Baltimore formation. She proposes the name Pickering Gneiss for the graphitic gneisses and the name is here credited to her although it has not yet appeared in print.

The Pickering gneiss is the important graphite formation of Pennsylvania, and all the graphite mines of the State have been opened in it.

The Pickering gneiss is a metamorphosed pre-Cambrian sediment that is composed primarily of feldspars, both orthoclase and plagio-

clase, quartz, biotite mica, hornblende, calcite, and much graphite. Less common constituents are pyrite, pyrrhotite, magnetite and their alteration products, limonite, epidote, zoisite, chlorite, allanite, titanite, zircon, sillimanite, and garnet.

The rock is extremely variable both in mineralogical composition and in texture. Some layers consist almost entirely of feldspar and quartz; some lenses observed in the underground workings of the Continental (Acme) mine are practically quartz schists; some layers or lenses contain much biotite and no graphite; some both graphite and biotite; while others show an absence of both these minerals.

The basic silicates or iron minerals are almost always present and the soils of the Pickering gneiss are almost invariably stained red by the limonite and hematite resulting from their decomposition. The soils can be used in mapping for this reason even where no outcrops occur. In Pickering Valley several limonite mines were formerly worked in the graphite gneiss and the washings from these mines contained much graphite as do also the limonite nodules. The miners early recognized the relation between the graphite-bearing beds and the iron-ore bodies. Observations seem to show greater amounts of pyrite and pyrrhotite in the beds containing most graphite, so it seems very probable that the graphite, or the carbonaceous matter that gave rise to the graphite, caused the original precipitation of the iron sulphides by the reducing action of the carbon. Later the iron sulphides formed the brown iron ore deposits through their decomposition by oxidation and the segregation of the oxidized products. In this decomposition of the original rocks, graphite is the only mineral present that seems to have remained unchanged. Even the greater portion of the quartz seems to have been removed and the clay in which the iron ore and graphite occur represents the residuum of the gneiss. In the open cuts of the Pennsylvania and Pettinos Bros.' mines at Byers the different stages in the process can be plainly seen.

The gneiss shows banding in most places, due to the parallel arrangement of the minerals, particularly the mica and graphite, and to partial segregations of the light and dark minerals in more or less distinct layers. In a few places the rock is even schistose in appearance.

That the Pickering gneiss has undergone intense squeezing is shown by the complicated dips and strikes of the beds and by the numerous faults. Slickensided surfaces are encountered frequently in almost all the mines and it is not unusual to have the rich graphite-bearing layers faulted to such an extent that they cannot be followed. Faults both parallel to the beds and at almost right angles to them have been encountered in the Pennsylvania Mine at Byers in close proximity.

Dikes of igneous rocks have been encountered in several places in the Pickering gneiss. In the quarry of the American Flake Graphite

Company a dike of basic rock varying from 3 to 8 feet in thickness cuts across the beds vertically. It is so badly decomposed that it is difficult to determine the original character of the rock. A little graphite obtained from the beds through which the dike was intruded was noticed in the outer portion but the interior of the dike is barren.

The graphite gneiss readily undergoes decomposition and in most mines in the State is so thoroughly decayed even at the lowest levels that the crushing of the rock is an item of small expense. There are exceptions to this, however, as will be explained in the detailed descriptions of the individual mines on a later page.

The graphite of the Pickering gneiss occurs in three forms: (1) as an important constituent of the rock evenly disseminated in interlocking grains with the other rock minerals, (2) in pegmatites, and (3) in small veins.

(1) The graphite, evenly disseminated throughout the rock, constitutes the bulk of the graphitic material of the Pickering gneiss and is the main source of supply. As stated above, some layers of the Pickering gneiss contain little or no graphite, while others contain so much mica accompanying the graphite that it is unprofitable to work them. An attempt was made to trace the workable beds of graphite throughout the Pickering Valley, but without much success. Some evidence has been obtained to indicate that the graphite bed worked by the Federal Graphite Company is a persistent bed that continues westward several miles and is the one worked in the Pettinos Bros.' mine, and the Pennsylvania mine, but the evidence is not conclusive. Certainly graphite flakes can be found in the soil all along a line drawn to connect those mines, but more exploratory work is necessary before it can be proved that the same bed extends so far. The Anselma mine seems to be sunk on a different bed, as do each of the other mines. It seems probable that rich and poor graphite-bearing beds in the form of more or less persistent lenses occur in many places throughout the Pickering gneiss.

The richer graphite-bearing beds are in some places sharply separated from the non-graphitic beds but more frequently one observes a gradual diminution in the amount of the graphite in the overlying and underlying strata. The thickness of the beds rich enough to warrant working varies greatly in the different mines. In some places the workable beds are only 6 to 10 feet in thickness and two or more beds may be worked in the same mine, while in other mines the total thickness of workable material in the bed has not been determined, but it is more than 100 feet. Naturally in the thicker beds there is somewhat more variation in the graphite content than in the thinner ones.

The amount of graphite contained in the Pickering gneiss varies so much that it is difficult to make any statement of the average

percentage. One operator in the Pickering Valley district claims that the rock worked for graphite contains an average of about 3% graphite; another maintains that the average is 6% to 7%; while individual mine operators claim that the ore which they work contains an average of 10%. Picked specimens have been analyzed and have yielded even higher percentages. Because of the marked variation in amount and the limited number of analyses available it is only possible to make a comparatively rough estimate. It seems probable that the average graphite content of the rock varies from 3% to 5% of which about 80% is recovered.

The graphite flakes of the Pickering gneiss seldom show hexagonal outlines such as those found in the limestone. They are thin, are arranged parallel to the bedding planes, and, in the main, vary in diameter from 1-16 to 1-8 inch, with the average probably about the mean of the two. In certain places the flakes are even larger than 1-8 inch in diameter and occasionally rather thick flakes are encountered. The thick flakes are less desirable because of the difficulty of recovering them by the flotation processes of concentration. The physical texture of the flakes also varies. In some places the individual particles of the flakes are so loosely bound together that in milling they are apt to be ground to a powder while others are harder and firmer and can be cleaned much more effectively.

(2) The second method of occurrence of the graphite of the Pickering gneiss is in the pegmatites that are abundant in almost every locality. In no mine have the pegmatites been worked exclusively as the source of the graphite. On the other hand there are few mines where the pegmatites have not yielded a consideable amount of the mineral.

The pegmatites vary in width from a few inches to 15 feet or more and have a considerably greater length and depth. They are mainly enclosed between beds of the gneiss, having the same dip and strike as the adjoining strata. However, it is not at all unusual to find the pegmatites cutting across the gneiss beds.

The pegmatites of the Pickering gneiss are so coarsely grained that they are readily distinguished from the enclosing layers of gneiss. They consist almost entirely of gray orthoclase and quartz in grains varying from one-fourth inch to one inch in diameter. The graphite present is also in large thick flakes, many of which are one inch or more in diameter. In some of the pegmatites the graphite is found evenly distributed throughout the feldspar and quartz with the flakes oriented in all directions but in others the graphite occurs in bunches of curved flakes. Many of the pegmatites contain graphite only in the outer portions while the interior is entirely devoid of it, which seems to indicate the surrounding rocks as the source of the graphite. The pegmatites were doubtless formed at the time that

the region was squeezed, folded, and faulted and the carbonaceous matter of the original rocks converted into graphite. If that is the case, the aqueo-igneous matter which formed the quartz and feldspar of the pegmatites picked up the carbonaceous matter of the rocks through which it passed and under the action of great heat and much aqueous vapor caused the carbon to crystallize in large flakes in the outer portions of the mass. Where the graphite occurs throughout the entire pegmatite body and shows no regular arrangement of the flakes it seems probable that the carbon in some form, perhaps as CO or CO_2, was an original constituent of the mass just as were the materials that gave rise to the quartz and feldspars.

Although the richest specimens of graphite can be obtained from the pegmatites, these bodies are of little economic importance. The average percentage of graphite is probably slightly less than in the surrounding rock and the graphite is of poorer quality. Bunches of practically pure graphite an inch or more in thickness may be gotten but the material is so friable that in the milling it is practically reduced to a powder and either lost or else recovered in the form of dust, the least valuable product. Also some of the thicker pieces are heavy enough to sink with the quartz and feldspars and pass into the tailings.

(3) The third way in which graphite occurs in the Pickering gneiss is in the form of veins. These are not common, yet have been observed in the old dumps of the abandoned mine near Trevose and in the mines near Chester Springs and Byers. No veins of greater thickness than three-fourth inch have been observed, although larger ones have been reported to occur.

The graphite in the veins is practically pure but less lustrous than that occurring as disseminated particles through the gneiss. It occurs in the foliated form with the plates or leaves projecting outward at approximately right angles to the walls of the enclosing rock. The leaves are somewhat curved and resemble closely the Ceylon graphite and were doubtless formed in the same way. These veins are so infrequent that they are of little economic importance in the graphite regions of this State.

Graphite is also found in the peripheries of gabbro intrusives in the Franklin limestones of Bucks county, in the basic gneisses of northern Bucks county, and in the slates and cement rocks of Lehigh and Northampton counties. None of these occurrences of graphite is of any economic importance.

RELATION OF THE FRANKLIN LIMESTONE AND THE PICKERING GNEISS.

In the above discussion the Franklin Limestone and Pickering Gneiss have been discussed as separate formations and it is probably advisable to map them as such because of the different economic uses of the two. Also in many places there seems to be a sharp line of separation between them. In other places, however, it is not possible to draw a sharp line and we have calcareous graphitic gneisses that might with equal reason be placed in either formation. We seem to have a duplication of the Grenville series of the Adirondack region where limestones, gneisses, schists, and quartzites occur in almost inextricable relationships. The workable graphite deposits of that state are contained in the Grenville rocks, mainly in the quartzites. These rocks are there believed to represent the metamorphic products of calcareous or siliceous shales. A similar explanation seems to satisfactorily explain the Franklin Limestone and Pickering Gneiss of Pennsylvania.

According to the above view the two formations were formed originally as contemporaneous sediments that varied in different places. In some localities fairly pure limestone was being deposited while in adjacent regions calcareous muds or siliceous muds in which there was little or no calcareous material were accumulating. When these sediments were later metamorphosed the beds composed mainly of calcareous matter formed the rocks called the Franklin Limestone; the calcareous muds gave rise to the calcareous graphitic gneisses observed in the underground workings of the Pennsylvania and Continental (Acme) mines; the muds with little calcareous matter formed the bulk of the Pickering Gneiss; and the more siliceous sediments formed the quartz schists such as occur in the lower levels of the Continental (Acme) mine. The quartz schist or quartzite phase is not well represented in Pennsylvania while in New York it forms perhaps the most important member of the Grenville series from an economic standpoint.

On the surface the relations described above are not readily apparent because of the solution of the greater part of the calcareous matter in the originally calcareous graphitic gneiss by percolating waters. We thus have outcropping only the two kinds of materials, the relatively pure crystalline limestone and the decomposed graphitic gneiss, consequently the line of separation between them seems to be rather sharp. Underground, however, where solution has been less effective the two grade into each other through the calcareous gneiss.

Although bedding planes are not apparent in the Franklin Limestone it seems probable that the limestone and gneiss are conformable. This conclusion is based on the fact that the limestone occurs in lenticular masses with the greatest length parallel to the strike

of the gneiss beds in some localities and probably such relations would be found to exist in other places as well if it were possible to obtain the necessary data. If, then, we can prove that the two formations are conformable, with the Franklin Limestone intercalated within the Pickering Gneiss, we have sufficient evidence for the view expressed above that the two are of contemporaneous origin and represent merely different lithologic phases of the same series of sediments.

ORIGIN OF PENNSYLVANIA GRAPHITE.

The graphite of Pennsylvania is believed to be of organic origin, with the possible exception of that found evenly disseminated throughout the pegmatites or that occurring in veins, and the rocks in which the graphite occurs are believed to be altered sediments. Certainly all evidence at hand seems to indicate that the graphite disseminated throughout the limestones and gneisses in the form of flakes has been derived from the carbonaceous remains of plants or animals, probably the former, mainly. Also in the case of those pegmatites in which the graphite occurs near the peripheries it seems probable that the carbonaceous material was derived from the adjacent sediments. The vein graphite and also the graphite evenly distributed throughout the pegmatites may, however, be of inorganic origin, as discussed more fully in a previous chapter.

The sediments that have given rise to the Franklin Limestone and Pickering Gneiss were probably shallow water marine deposits, as is indicated by the variation in lithological composition. Such conditions would furnish favorable places for the growth of marine plants whose remains would be enclosed in the strata. Later when earth adjustments took place and the strata were squeezed and folded the resulting pressure and heat are believed to have converted the amorphous carbon into crystalline graphite just as graphite is formed in cast iron when it cools. It is well known that at a high temperature the molten iron absorbs a considerable quantity of amorphous carbon which it liberates in the crystalline form on cooling. Heat and pressure such as occur in the artificial process occur in nature when the rocks are greatly compressed and with similar results. In a preceding chapter on the "Origin of Graphite" a more detailed description is given.

Regional or dynamic metamorphism has been the main cause of the formation of the Pennsylvania graphites, but the effect of contact metamorphism is also apparent. The numerous pegmatite dikes that have been injected into the gneisses to such an extent that, in many places, they are properly called injection gneisses, have caused the formation of larger flakes of graphite in their immediate vicinity than elsewhere in the gneiss.

CHAPTER X.

MINING METHODS.

In most places in Pennsylvania, graphite ore has been mined in open cuts. The ore beds outcrop and the surface ores are richer and more easily worked because of the ore being so greatly decomposed by weathering action which has caused some of the constituents of the rock to be removed without affecting the graphite. The beds dip rather steeply 30° to 50°, in most places, and the open cut method of working is continued until the overburden of barren rock becomes too great for easy removal when vertical shafts or inclined slopes are sunk. The open cuts are usually continued until they are 30 to 40 feet in depth.

Inclined slopes folowing the ore bed are common throughout the region. At about the depth of 50 to 70 feet drifts are run in the ore bed along the strike and stopes are carried upward in the bed at varying distances. Not uncommonly these stopes are carried up to the open cuts and waste materials from the cuts are later used to fill them.

In most places the graphite ore and also the slightly graphitic wall rock is so greatly decomposed that considerable timber must be used, and even then caving often takes place. Almost every one of the older mines has many bad places where the timbers have been crushed by the falling of the rotten overlying rock.

Both in the open cuts and in the underground drifts the cars are trammed by hand to the foot of the incline or shaft where they are hauled up to the mill by cable.

In many mines the ore is so greatly decomposed that very little blasting is done. The ore is loosened by picks and shoveled in the cars. The mining does not offer any special problems, little skill being demanded except in timbering, and unskilled labor can be employed in practically all phases of the mining operations.

CHAPTER XI.

CONCENTRATION OF PENNSYLVANIA GRAPHITE.

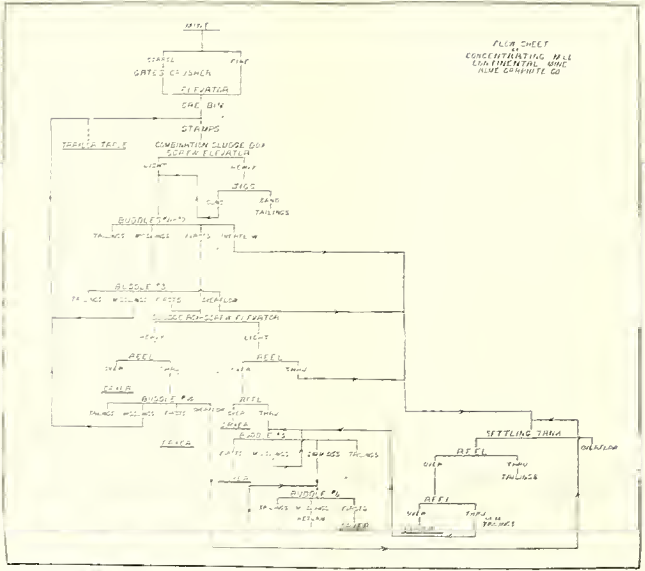
The greatest problem confronting the graphite operators of Pennsylvania, as well as those of most other states, is the economical and efficient separation of the graphite from its associated gangue

minerals. These associated minerals may be divided into two classes: those minerals that are loosely associated with the graphite particles and easily freed and those smaller impurities that are intimately associated with the graphite and commonly lie between the thin laminae of the graphite flakes.

The cleaning of graphite in most mills is divided into two stages which are, in a general way, concerned with the removal of these two kinds of impurities. In the first stage, termed the concentration process, the ore as it comes from the mine is crushed and treated in various ways to free the coarser and loosely adherent impurities, the resulting product being called "concentrates." The further cleaning of the graphite by finer crushing and screening by which the more firmly adherent impurities are removed is designated the "refining" process and the product called "refined graphite." In both processes the object is the same but the methods, as well as the types of machinery employed, are, in most mills, quite unlike.

At the present time the cleaning of graphite is in the experimental stage and there is much more work to be done before the problems can be said to have been solved. To a certain extent the problems encountered by each operator are unique as slight differences in the mineralogical composition of the ore may compel operators in nearby mines to instal decidedly different types of machinery. In some instances, even in the same mine, the ore may vary sufficiently as the work is extended to make it necessary to alter the concentration process. The fact that those companies that have a rather uniform kind of ore in their mines are also frequently making changes in the methods of concentration is further evidence of unsolved problems. There is far more secrecy among graphite producers in regard to the milling methods employed than in almost any other kind of ore separation and many companies in the eastern part of the country refuse to admit visitors to their mills. The extremely small probability of one company profiting by the experience of another and thereby injuring its market through increased competition would seem to indicate the uselessness of secrecy employed by so many graphite companies. On the contrary there is little doubt but that the increased prosperity of one company would have a beneficial effect on all others in the district, at least until the production increased far beyond its present proportions, and the problems of concentration might be more speedily solved under the plan of co-operation and mutual assistance.

The problems encounted in the separation of disseminated graphite from its associated minerals are numerous and difficult. The ordinary processes of milling are reversed as in graphite concentration it is the mineral with the lowest specific gravity that must be saved. The separation must be a gravity one and the difference in specific gravity of graphite and its most commonly associated minerals, quartz


FLOW SHEET
CONCENTRATING
CONTINENTAL
GATES CRUSHER
ELEVATOR
ORE BIN
STAMPS
COMBINATION SLUDGE BOX
SCREW ELEVATOR
LIGHT
HEAVY
JIGS
TAILINGS
REEL
OVER
THRU
SETTLING TANK
OVERFLOW

and feldspar, is so small that the process is a delicate one and a slight change in the adjustment of the machines might seriously affect the separation. As stated on a previous page, graphite has a specific gravity of 2.09-2.23, quartz 2.65-2.66, feldspar 2.47-2.67, calcite 2.71, mica 2.7-3.1. The less common minerals such as hornblende, pyroxene, pyrite, pyrrhotite, epidote, scapolite, and limonite with specific gravities much higher, are easily separated from the graphite except when firmly adherent to the graphite flakes and even then can be loosened by fine grinding after which gravity separation can be readily accomplished.

In Pennsylvania, New York, Ontario and other places where disseminated flake graphite occurs, two radically different methods of concentration have been tried, viz.: the wet flotation process and the dry pneumatic process. Probably the majority of companies have tried both processes. In Ontario the dry method seems to meet with more favor while in Pennsylvania no company has been successful with it. In several of the older mills in this State the discarded pneumatic separators can still be found.

The process of cleaning the graphite, as previously stated, is divided into two parts, the concentrating and refining. Each of these is in turn divided into two stages, viz.: the crushing or grinding and the separation of the minerals. In addition, at least once and sometimes twice during the process, the ore or concentrates are passed through a dryer.

In the descriptions that follow the four stages will be briefly described under the following headings: (1) Initial crushing of ore. (2) Separation to form concentrates, (3) Re-crushing the concentrates, and (4) Classification of concentrates.

INITIAL CRUSHING OF ORE.

Graphite ore of Pennsylvania consists of two kinds, the hard ore and the soft decomposed ore. Most of the mines are operating in the soft ore where a minimum amount of crushing is required but in some cases the graphite is contained in hard rocks that have undergone very slight changes and where the crushing is a matter of considerable importance.

In the crushing of graphite considerable care must be taken because of the softness of the graphite which causes it to break into small pieces much more readily than the accompanying minerals. The larger the flakes the higher price can be obtained for the product, consequently it is advisable to crush the ore only enough to secure the maximum amount of large clean flakes and a minimum amount of graphite dust and yet without losing too much of the graphite in the tailings because of incomplete crushing and imperfect separation of the graphite from adherent minerals of higher specific gravity.

The crushing of graphite rock is sometimes rather difficult because of the lubricating action of the graphite.

In most of the Pennsylvania mills the graphite ore as it comes from the mine is passed over grizzlies and the coarse material thence goes to a coarse crusher while the fines go directly to a fine crusher or to stamps or Chilian mill. Jaw crushers, such as the Blake crusher, are employed in most mills but in at least one mill a Gates gyratory crusher has been installed. The second crushing is done in rolls, Chilian mills, or stamps. There is considerable difference of opinion concerning the relative merits of the three. In some places the stamps have been found to be ineffective for crushing of graphite ore because of the tendency for the wet graphite to be worked into a cylinder with smooth polished interior through which the stamp falls with practically no effect.

SEPARATION TO FORM CONCENTRATES.

After the ore has been crushed the next step is to separate the graphite from the other minerals. In the crushing the graphite and mica have been broken into thin flakes while the quartz, feldspar, kaolin, and other brittle or pulverulent minerals have been broken into angular fragments. The shape of the graphite and mica renders them more easily held in suspension in running water and they can be floated off regardless of the fact that they are more than twice as heavy as the water.

In the wet process many devices for flotation of the graphite flakes have been used. Perhaps one of the simplest, but nevertheless very efficient, machines used in many mills is the log washer. The angle of inclination of the screw must be carefully determined by experiment in order that the graphite and a minimum amount of impurities may be floated off at the lower end of the box and a minimum amount of graphite permitted to settle in the box and forced out of the upper end of the box by the revolving screw.

In at least one place a concentrating Overstrom table was installed, but it seems to have been unsuccessful because of the large amount of middlings produced.

Buddles have been extensively used in the Pennsylvania mills and have been fairly successful. The amount of labor involved in their use has caused some operators to abandon them. There seems to be no satisfactory way of getting the concentrates, middlings, and tailings out of the buddles except by hand shoveling, which is both slow and expensive.

The buddles consist of circular tanks about 3½ feet in depth and about 16 feet in diameter. The ore from the crusher is mixed with much water and poured into the tank in the center. One or more revolving arms attached to a central shaft keep the water agitated

sufficiently for the graphite to be mainly floated to the side of the tank while the impurities remain near the central shaft. After the tank is filled, the material is allowed to partially dry and is then shoveled out. The outer portion is composed of rather clean concentrates, the middle portion contains both graphite and impurities and must be passed into another buddle, while the inner portion, consisting of sand tailings, is discarded.

The Brumell separator has also been used in the Pennsylvania district in at least two mills. It has been described* by its inventor in the following words.

"This is a method, rather than a machine, and relies upon the floatability of graphite, when dry, upon, rather than beneath, the surface of water. The apparatus employed is a square wooden box, twenty feet in length by four feet wide and five feet deep, filled with water and with a surface current extending across its width, obtained by jets projected against the side at an upward angle of 45° and about nine inches below the surface. This box is hoppered along the sides, the cants throwing the tailings into a worm conveyor which, in turn, conveys the refuse to an elevator with perforated bucket, the chain of which actuates the conveyor. The dried ore is fed to the surface near the side over the jets by means of a spiral steel conveyor enclosed in a tube with a longitudinal slot the entire length, and passing over a glance board, is dropped about one-half an inch in a thin curtain to the water. The graphite which remains floating is carried over into the settling tank, hoppered to the center, where it is wetted, and drops through an opening into a spiral steel conveyor enclosed in a tube and inclined at an angle of 45°, from whence it is fed automatically to a revolving steam dryer. The water passes over and under several steps and eventually escapes through a screen at the opposite side. This apparatus, while very economical as to power and capacity and entirely automatic, is, at best, only a rough concentrator rarely bringing a 10 per cent. ore up to 65 per cent., and in consequence is not now in use."

In connection with the machines just described, revolving screen reels are commonly used. These reels are hexagonal and are covered with screens of various sized mesh. The reels are slightly inclined; the ore is fed into one end and the concentrates thrown out at the opposite end as the reel rotates. Jets of water directed against the outer part of the reel aid in the separation of the graphite and impurities. The latter because of their smaller size pass through the screens and are thrown away. From the reels in some mills the concentrates are thrown on a gently sloping cement floor where jets of water wassh the flake off more readily than the particles of sand that

*Canadian Min. Jour., Vol. 30, p. 270, 1909.

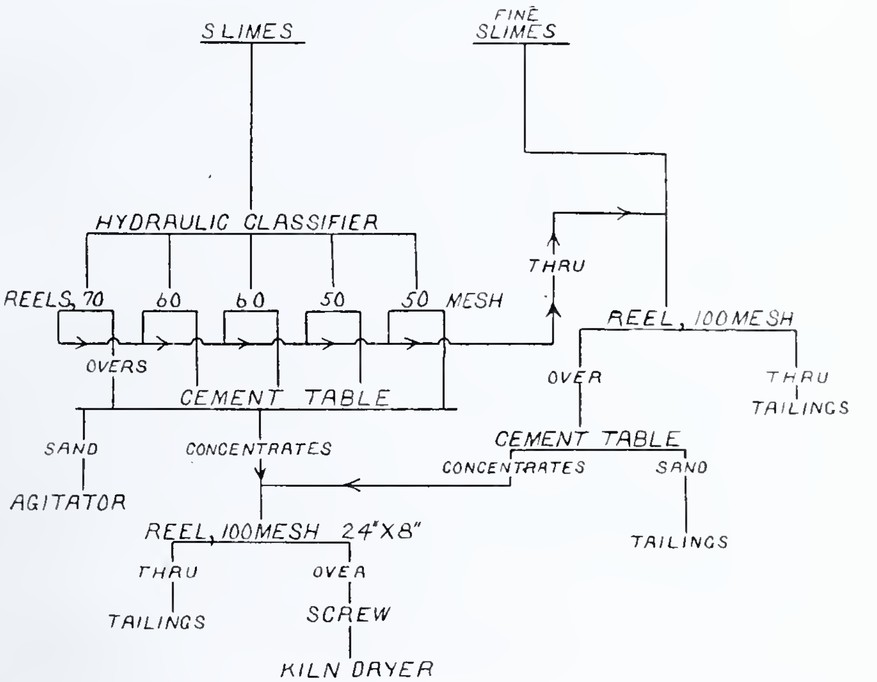
might have passed through the end of the reel with the graphite flakes and thus produce a further concentration. The mica flakes also tend to adhere to the cement floor.

It has long been known that a thin film of oil on the surface of water would tend to hold the graphite flakes on the surface and thus aid in the separation of the graphite from the sand by flotation. Various devices for making use of this principle have been devised, most of which are fairly successful. If oil is used at all it is commonly employed to concentrate the material brought from the reels, log washers or buddles.

In one mill in the district a Wetherill magnetic concentrator was purchased after experiments had been made with it at the Massachusetts Institute of Technology, which were said to have proved its usefulness. The ore was first roasted probably for the purpose of breaking up the biotite and converting the iron of that mineral into metallic iron. The material was then passed under the magnets which were supposed to pick up many of the impurities. In practice the magnetic concentrator was a failure.

Although no dry concentration has been done in the Pennsylvania graphite mills for many years it may not be out of place to include a description of the Hooper pneumatic concentrator which has been tried in one or more mills.

"This machine consists of a flat chest containing a diaphragm actuated by eccentrics on a driven shaft running horizontally beneath the chest, and this chest, in turn, is surmounted with a movable deck of a peculiar design, the two separate parts being connected with a hollow ball and socket joint. The eccentrics, which are adjustable, act upon the diaphragm causing pulsations of air to pass up through the ball and socket joint and through a second diaphragm immediately below the deck which consists of a cast iron grating covered with broadcloth. Over this grating is the concentrating top, consisting of a cast iron frame with parallel strips of sheet brass extending diagonally from side to side, and these in turn are surmounted by another set of parallel strips diagonally in the other direction. The ball and socket joint permits of the top being set at any vertical or lateral inclination. The ore is fed to the upper end of the concentrating top and is aided in its travel to the lower end by the rapid pulsations of the air which pass up through the broadcloth, effecting at the same time a concentration according to gravity. The lower brass strips, or riffles, carry the heavier portions to the lower side of the deck while the upper brasses or channels carry the lighter or top stratum diagonally to the upper side. At the discharge end of the deck are finger pieces which guide the various products to their respective receptacles. These machines require very accurate sizing of



FLOW SHEET
for
TREATMENT of SLIMES
PENNSYLVANIA MILLS

material and when once set as to eccentric throw, speed and vertical and lateral inclination, require no further care beyond cleaning the broadcloth bed which should be done about every five hours."*

RE-CRUSHING OF GRAPHITE CONCENTRATES.

In some mills no attempts are made to further clean and classify the concentrates, but after drying they are at once marketed. The concentrates contain some large flake material that may be worth more than 6 cents a pound and much graphite dust that is worth less than 1 cent a pound, together with many fine particles of quartz and other materials attached to the flakes of graphite or included between the laminae. The mica which has been rendered more brittle during the drying process can also be pulverized more readily in regrinding and so separated from the graphite flakes. The flakes are also broken into thinner pieces and acquire a bright polish. In these stages the methods employed in all the Pennsylvania mills are much the same. The kind of machinery employed is mainly that used in the manufacture of flour.

The concentrates from the dryer are elevated to a bin from whence they can be fed into rolls or buhrstone mills. In such machines the flakes on account of their flexibility and shape tend to flatten out and while pulled apart along cleavage lines are not materially disintegrated, while the more brittle minerals are broken into fine powder. Most mills use both steel rolls and buhrs and the material is ground several times to obtain the desired product. The more frequently the flakes are ground the cleaner the graphite becomes, but the proportion of graphite dust in comprison with the flake also increases with each regrinding and care must be taken to produce as large an amount of high-grade flake as possible because of its higher market value.

The rolls are smooth and are set with a slight differential. They are usually arranged in several sets and the middlings are brought back from certain reels to be again re-ground. In the soft ore the flakes undergo a minimum amount of disintegration in the rolls or buhrs but in the hard ore some angular pieces of quartz or other hard minerals that may be mixed with the flakes tend to tear the graphite into small pieces and convert much of it into a powder.

CLASSIFICATION OF CONCENTRATES.

From the rolls or buhrs the concentrates are passed through various flour mill reels to classify the materials. The process is similar to the separation of the flour and bran in a flour mill. Successive reels have fine wire or silk cloth with various sized meshes for the separa-

*Canadian Min. Jour., Vol. 30, pp. 271-272, 1909.

tion of the larger and finer particles. The details of the construction of the reels, the kind of wire or cloth used, and the arrangement of the reels vary in the different mills, but the principles are the same.

Among the Pennsylvania graphite operators five grades of concentrates are commonly produced which have received various local trade names. The names employed by several companies are in the order of their desireablity, mainly dependent upon the size of the individual flakes, as follows: No. 1 Crucible, No. 2 Crucible, No. 90, No. 1-19, and No. 2-90. The first three are called flakes and the latter two dust. The Pennsylvania Graphite Company has used the name "Super X" instead of No. 2 Crucible and also uses the name "Lubricating" for a soft flake unusually free from grit. The Acme Graphite Company at one time classified their concentrates into six kinds of flake and three kinds of dust designated as No. 1 Flake, No. 2 Flake, etc. The Imperial Graphite Company, now superseded by the Eynon-Just Graphite Company at one time marketed their product under the trade names of Massachusetts No. 1, Covington No. 2, Massachusetts Super X, Massachusetts No. 2, Covington No. 90, Massachusetts No. 90, and Massachusetts Dust. The exact equivalents of these terms in the more common nomenclature is not known.

CHEMICAL REFINING OF GRAPHITE.

Since graphite is so slightly affected by chemicals it is possible to remove many of the impurities by simple chemical treatments. The Germans and Austrians have used some chemical methods economically and have produced practically pure graphitic carbon. It seems highly improbable that their methods could be profitably employed in the refining of low grade disseminated graphite ores such as we have in the United States and few experiments of the kind have been made. The Federal Carbon Company is said to have tried a method of chemical refining at one time, but it did not prove successful. Little information is available concerning the process tried.

The material obtained by the chemical refining of graphite is amorphous and consequently unfit for various purposes for which flake graphite can be used. Such graphite would come into competition with the high grade Mexican and Korean graphites which can be obtained for much less price than the flake graphites.

ECONOMIC CONSIDERATIONS IN THE CONCENTRATION OF GRAPHITE.

Prof. F. D. Chester, the General Manager of the Chester Graphite Company has so well described the problems of graphite concentration in an article* published a few years ago that it is here quoted in its entirety.

*Eng. and Min. Jour., Vol. 88, pp. 824-825. 1909.

"A number of graphite ventures have been a financial failure because of the low percentage of extraction. Occasionally this loss amounts to as much as 50 per cent., which is equivalent to handling an ore of half value, and as the expense is the same and the output one-half its theoretical amount, the yields may be insufficient to give a profit. Besides an efficient extraction, it is important that the resulting concentrates be as clean as possible, and in this respect some of the mills have failed.

CONCENTRATION OF THE ORE.

"Flake graphite as it occurs in nature, freed from every trace of associated gangue matter, is not a pure mineral, but one made up of a series of laminations between which are lodged variable amounts of mineral impurities varying from 10 to 25 per cent. To remove the latter, so as to bring the flake to a state of maximum purity and high carbon, these thicker flakes have to be split up, and the resulting thinner flakes rubbed clean of adherent impurities. This has so far been done on stone mills. By the grinding not only are the flakes delaminated, but the more brittle mineral impurities are ground to dust, which is subsequently bolted out from the larger more resistant flake. This process is repeated as many times as is necessary to give the flake the necessary thinness, and until it is essentially clean of foreign matter. This process of refining is applied to the dried concentrates, and the losses in the milling are largely dependent on purity of the concentrates.

"I have been in mills which have made it a practice to grind concentrates which would not run over 25 per cent. of carbon, and there are few instances where these concentrates will run over 40 per cent. The milling of a sandy concentrate is ruinous, since it cuts the flake or grinds it to dust, and carbon in the form of dust is not worth over 3 cents per lb., while as flake it is worth from 7 to 7.5 cents.

LOSSES CURRENT IN MILLING.

"In order to give the losses current to milling a definite expression, the following formula has been derived, which gives results which I have found agree quite closely with the practice. In this a pure flake is assumed to contain 90 per cent. of graphitic carbon. If, then, a concentrate assays 60 per cent. of carbon it means that 30 per cent. of foreign matter has to be ground out of this concentrate, which gangue matter in the form of dust is mixed with more or less reduced flake.

"It has been found that in the operation of grinding a concentrate twice, the average percentage of carbon in the resulting dust will vary from 30 to 40 per cent., depending upon the character of the

concentrate, so that from these data it is easy to determine the theoretical proportions of pure flake to dust from a given concentrate.

Thus let

W = Weight of the concentrate in pounds,
F = Weight in pounds of pure flake recovered,
C = Percentage of carbon in the concentrates.

Then

$0.90 - C$ = Percentage of impurities to be removed $= S$,

and WS = Weight of impurities in W.

Let P = Average percentage of carbon in the total dust produced,

and X = Total weight of dust produced,

$$X = WS + PX = \frac{WS}{1 - P}.$$

Then

$$F = (W - WS) - \frac{WS}{1 - P} - WS = W - \frac{WS}{1 - P}.$$

"On the basis of the latter formula, we would get the results shown in the accompanying table from lots of 2,000 lb. of concentrates of different percentages of carbon.

RESULTS FROM 2,000 POUND LOTS ACCORDING TO FORMULA.

Percentage Carbon in Concentrates.	Refined flake produced, lb.	Total dust produced, lb.	Pure carbon in dust, lb.	Value of flake produced at 6¼c. net.	Value of dust produced at 3c. per lb. for carbon.	Total value of flake and dust.	Average value per pound of product.
40,	334	1666	666	$20 87	$19 98	$30 85	1.54c.
50,	667	1333	533	41 69	13 39	55 68	2.71
60,	1000	1000	400	62 50	12 00	74 50	3.70
70,	1429	573	171	89 51	5 13	94 44	4.70
80,	1715	285	85	107 18	2 55	109 73	5.48

"From this it is seen that the money value of the product of a mill is largely dependent on the character of the concentrate, and how important it is to bring these concentrates to the highest attainable degree of purity before they are ground. Of course, a mill handling a given tonnage of ore per day will produce a larger quantity of a

low-grade concentrate than of a higher, and the output of a mill can be run up by grinding a lot of sandy concentrates, and making an equivalent amount of low-priced dust at the expense of flake, but, as has been shown, this is not profitable.

"To get at the matter more exactly we will consider 1,000 lb. of an 80 per cent. carbon concentrate as the highest ideal standard, then with lower percentages of carbon in the concentrates the quantities and values will be somewhat as appear in the second table. From this it is seen that between a concentrate of only fair value as usually encountered, and running 40 per cent. of carbon, and one of maximum purity, there is a loss of value from milling of nearly 44 per cent. If, then, a mill is capable of producing 2,000 lb. of an 80 per cent. concentrate, or 4,000 lb. of one averaging 40 per cent., it makes considerable difference in the profits whether the output from these two grades of concentrates be $109 or $60, possibly the difference between a profit and a loss.

"It is also seen from the accompanying table that the difference between an 80 and a 70 per cent. concentrate is not great enough to pay for the extra cost of refining above the 70 per cent. limit. But that below 70, while the percentages of carbon in the concentrate decrease in arithmetical ratio, the values of the product decrease in something like geometrical ratio.

QUANTITIES AND VALUES OF VARIOUS CONCENTRATES.

Percentage of Carbon in Concentrates.	Proportionate weights of concentrates in lb.	Average value of flake and dust produced.	Percentage of loss in value.
80,	1000	At 5.48c. $54 80	0
70,	1143	At 4.70 53 72	1.97
60,	1333	At 3.70 49 32	10.00
50,	1600	At 2.70 43 20	21.20
40,	2000	At 1.54 30 80	43.90

SUMMARY OF COMMERCIAL CONSIDERATION.

"It may now be asked, is there any set of conditions which will determine the profitable production of graphite, and which may be applied to any enterprise. An attempt might be made to answer the question as follows: (1) A cost of mining not to exceed 50c. a ton, and of milling not to exceed 75c.; (2) a yield of marketable graphite, calculated as graphitic carbon, of not less than 40 lb. to

the ton of ore handled; (3) the production of a concentrate to contain not less than 65 per cent. of carbon; (4) a return from the sale of the product of not less than 7c. per lb. for the actual carbon in the refined flake, and of 3c. per lb. for the actual carbon in the dust. Under these conditions an ore yielding 40 lb. of actual carbon will be worth approximately $2 a ton and a mining and milling cost of $1.25 a ton, will leave a profit of 75c. a ton.

"Thus it appears that a mill must have a rather large tonnage capacity to realize much of an interest on the investment, cover repairs, renewals, and provide a sinking fund to redeem the investment within the productive life of the mine.

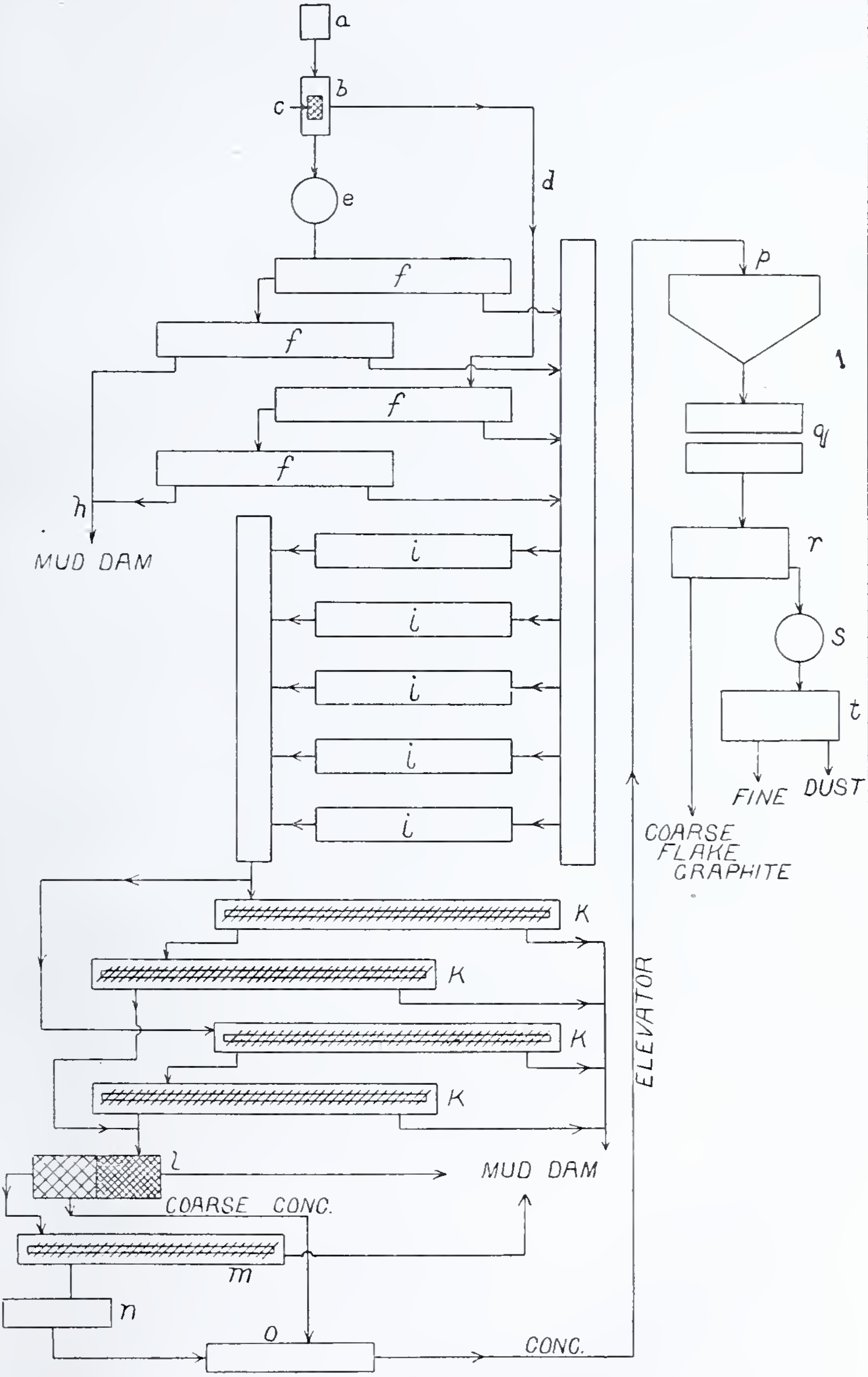
"It must be understood that a low-grade graphite ore at the existing price of the product will not pay for deep mining at any greater cost than enumerated. From what has been written it will not be difficult for the officers of a company, not satisfied with results, to institute an inquiry, and to determine the real condition of affairs existing. Very often officials and stockholders realize that something is wrong in their company without knowing the cause, and the employees, anxious to retain their positions as long as possible, make plausible showings of total output; the financial balance, however, is always on the wrong side."

SPECIFIC EXAMPLES OF MILLING METHODS.

For purposes of illustration the flow sheets of two of the mills in the Pickering Valley district are given with the accompanying descriptions. The author is indebted to the officers of the two companies for the information.

CONCENTRATION OF ORE BY CHESTER GRAPHITE COMPANY. (PLATE V.)

The ore as it is trammed from the mine is dumped into a hopper feeding the crusher (a), the latter being fed with water from a 1-inch pipe. It is discharged into an inclined launder (b) containing a screen (c) with three-eighth inch holes. The undersize passes directly to the log washers (f) through a launder (d) while the oversize is fed to a 6-foot Chilian mill (e). From the mill the overflow passes into the log washers (f) arranged in double series. They are inclined toward the launder (g). The screw of the washers works the sand toward the head where it is discharged (h) and goes to the mud dam. The overflow carrying the muddy water, graphite flake, and some fine sand goes into the launder (g). From the latter, the material separates and passes through five octagonal screens, termed "float reels," arranged in a parallel series. As the reels revolve slowly a perforated pipe over each allows water to flow over the screens. The water tends to separate the flake and fine sand. The fine sand and



FLOW SHEET
CHESTER GRAPHITE CO.

muddy water passes through the 60-mesh screens and is thrown away. At the lower end of the reel flake graphite with some sand is discharged into a launder (j) from whence they pass through a number of sand screens (k) arranged in double series. To the latter, oil is added to collect the graphite and aid in floating the flakes. The sand sceens are similar to the log washers, the sand being pushed toward the upper end where it is discharged and carried to the mud dam. At the lower end the graphite flakes float off and pass to a revolving screen (l), half of which is covered with 60-mesh and the other half with 30 mesh wire cloth. The material is fed into the end of the screen covered with the finest cloth. That which passes through is fine sand and dust which is discarded, while the oversize passes to the coarser part of the screen. The material which is discharged at the end of the screen passes to another sand screen (m) which is also fed with oil and revolved very slowly, about one revolution per minute. The sand worked by the screw to the upper end runs to the mud dam while the graphite floated off at the other end goes to a square buddle (n). The latter classifies the material into three grades; fine graphite which has been separated from the sand and which goes to the wet concentrate stream from the screen (l), middlings which pass over a traveling belt carrying them back to the log washers (f), and tailings of fine sand which run to the mud dam.

The wet concentrates consisting of a coarse and fine flake pass to the revolving dryer (o) and are then elevated to a bin (p) on the upper floor. From the bin they are fed into a pair of smooth close-set rolls (q) and thence to a bolting reel (r). The reel is covered with No. 64 grit gauze bolting cloth. The oversize is coarse flake finished graphite and is collected in bins; the undersize passes through a buhrstone mill (s) and thence to a second bolting screen (t) covered with No. 9 bolting cloth. The oversize from this screen is fine flake, while the undersize is graphite dust. The coarse and fine flakes average about 75% graphitic carbon while the dust is lower. The amount of graphite recovered from the ore is about 83% on an average.

CONCENTRATION OF ORE FROM CONTINENTAL MINE, ACME GRAPHITE COMPANY, (PLATE III).

The ore of the Continental mine is hard ore as distinguished from the disintegrated ore of most of the mines. As it comes from the mine it is dumped into an ore bin over a 2-inch grizzly, the fine material going direct to the stamps, the coarse to a Gates gyratory crusher. The mill is fitted with ten 850-pound stamps. The ore is crushed fine enough to permit it to pass through 8-mesh wire cloth.

The best results have been obtained by using mesh of that size; a less fine crushing would not free the graphite from the gangue minerals, while a finer crushing pulverizes too much of the graphite.

From the stamps the ore goes to a combination settling box and screw conveyor set at an angle of 20° to the horizontal. The float or overflow passes to 20-foot buddles, the coarser materials to a jig. The tailings from the jig are thrown away while the concentrates, if sufficiently clean, go directly to the reels, otherwise to the buddles.

The mill is equipped with six buddles, the first two are filled and cleaned alternately, while the others are used to clean the middlings from the first two and from the reels. From the buddles the concentrates are passed through hexagonal reels, the oversize going to the dryer and the middlings through buddles. The tailings come entirely from the buddles and jig while the concentrates sent to the dryer come in part from the reels and in part from the buddles. The overflow from the first buddles passes to a settling tank and thence to the reels. The arrangement of the reels and buddles is shown on the accompanying flow sheet.

The refining of the flake was done in the ordinary manner and the accompanying flow sheet requires no description. This company produced some very fine flake containing more than 90% graphitic carbon.

In this mill a Wetherill magnetic concentrator, an Overstrom table, and a ball mill were experimented with, but were found to be unsuitable.

CHAPTER XII.

DESCRIPTIONS OF INDIVIDUAL PROPERTIES.

As stated on a previous page, the graphite deposits that have thus far been worked or prospected carefully are confined to four counties, —Chester, Berks, Lehigh and Bucks. In the following pages these are discussed in the order named which is the order of their relative importance. No attempt is made to describe every locality where graphite has been observed, but only those places where some development work has been done. There is little doubt, however, but that there are many other localities, especially in Chester county, where equally valuable graphite deposits occur, judging from the fragments of graphitic gneiss and graphite flakes found in the soil.

GRAPHITE MINES OF CHESTER COUNTY.

For many years the chief center of the graphite industry of Pennsylvania has been Chester county, where almost continuous mining

has been carried on since about 1870, while one mine was operated several years earlier. During the past 10 years all the graphite mining of the State has been confined to this county.

The graphite mines of Chester county are located in the valleys of Pickering and French creeks. The French Creek deposits were the first ones to be worked and one active mine was located in that valley near Coventryville. The Pickering valley region, however, which is traversed by a branch railroad line, is the main graphite district both of the county and the State and 10 different mines with well-equipped mills have been operated there at different times. Besides these mines, much prospecting has been done in other places in the same district with promising results.

AMERICAN FLAKE GRAPHITE COMPANY.

The American Flake Graphite Company's property is located on Phoenix Hill, 1½ miles south of Kimberton and 3 miles southwest of Phoenixville. The company was incorporated in July 1908 and soon began the erection of a mill. Operations were started in 1909 and were continued intermittently until the spring of 1911 since which time the property has been idle. The mill was enlarged and practically rebuilt in 1910 at considerable expense, but was run only for a short time. It has now been dismantled.

The ore is a fine grained gneiss composed of kaolinized feldspar, quartz and graphite, with a small amount of biotite and pyrite. The graphite flakes vary from 1-16 to 1-8 inch in size. At the surface the rock is very rotten and some segregations of limonite iron ore occur in the residual graphitic loam.

Pegmatite dikes are numerous and consist of blue quartz, orthoclase, coarse graphite flakes, and nests of foliated graphite.

The strike of the ore beds is N. 10° to 15° E., with a dip of about 35° S. E. The thickness of the beds worked is about 30 feet but similar beds seem to underlie these and the total thickness has not been determined.

The ore averaged more than 3% graphite at first but decreased somewhat later. The cause for the closing of the plant was the encountering of a vertical dike of basic rock about 8 feet in thickness which extended across the entire quarry completely cutting off the graphite ore. The dike is so badly weathered that its original minerals cannot be accurately determined, but it seems to be diabase. A few flakes of graphite caught up from the surrounding rock were observed in the sides of the dike. The removal of this large amount of barren rock increased the cost of production to such an extent that it was impossible to make any profits and the plant was accordingly abandoned.

The ore was obtained from an open quarry in the side of a hill and was drawn up an inclined trestle by cable to the top of the mill where it was dumped into an ore bin.

Difficulty was encountered in getting a sufficient supply of water for concentrating the ore until pipes were laid to Pickering Creek about three-fourths mile distant. Wells that were sunk in the hill near the mill did not furnish an adequate supply.

The mill was well equipped with machinery consisting of crushers, rolls, log washers, reels, drier, buhrstone mills and bolting reels. The ore was crushed fine enough to pass through a No. 10 mesh screen and then run through log washers which separated the greater portion of the sand from the graphite flakes. The graphite passed from the washers to a screen-shaker and wet reels. To separate the mica from the graphite a V-shaped trough, 3 feet in height and with a $\frac{1}{4}$-inch opening at the bottom was built and above it was placed a perforated $\frac{1}{2}$-inch pipe through which water flowed. The jets of water washed the flakes of graphite and mica out of the trough to a slightly sloping cement floor. The General Manager, Mr. J. Warren May, claimed that the graphite washed across this cement floor while the mica adhered to it.

The graphite concentrates were then dried at a temperature sufficient to burn any particles of wood that might have been mixed with the ore in mining or milling. The concentrates are said to have contained from 80% to 86% carbon.

In the finishing mill the concentrates were reground in French buhrstone mills and passed through flour reels. The refined graphite contained from 90% to 96% carbon. Three varieties of flake and one of dust were produced. The largest flake product was sold for the manufacture of crucibles, the medium flake for lubricants, and the small flake for stove polish and paint. The dust was sold mainly for foundry facings.

GIRARD GRAPHITE COMPANY.

The mine and mill of the Girard Graphite Company are located one mile northwest of Hallman, a station on the Pickering Valley Branch of the Philadelphia and Reading Railway.

In 1905 the mine was opened and a mill equipped under the name of the Husbands' Graphite Company. The production for that year was about 25 tons of flake graphite. In 1907 the property was sold to other parties who organized the Girard Graphite Company. It was worked by this company for about a year and then closed and the mill partly dismantled. In the spring of 1911 the property was sold by the sheriff and the machinery was entirely removed.

The mine is located beside an old open pit of a limonite iron mine worked many years ago. The pit, now partly filled with water, is

Fig. 1. Mill of American Flake Graphite Company, Kimberton.

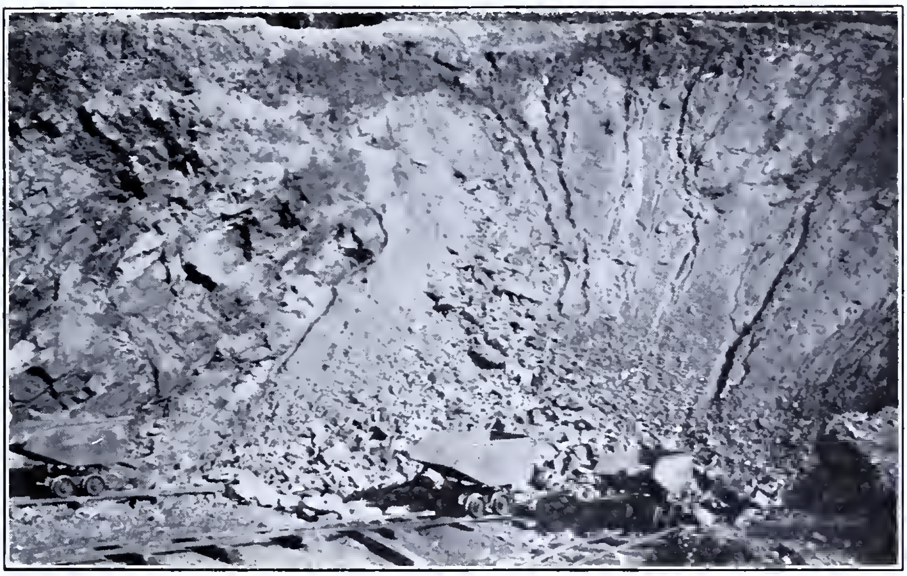


Fig. 2. Quarry of American Flake Graphite Company, Kimberton.

about 400 feet in length and 300 feet in width. A vertical shaft 40 feet deep was sunk near the edge of the pit and the mill is close by.

No rock in place can be seen at the present time, but specimens obtained from the mill consist mainly of limonitic clay carrying masses of limonite, quartz and flakes of graphite and biotite. The rock originally was probably a calcareous pyritiferous gneiss in which the pyrite has been altered and segregated to form limonite iron ore, the feldspar has changed to kaolin, and the calcite has been carried away. Many of the masses of compact limonite contain flakes of graphite. The graphite flakes are of good physical character, although rather thick to be easily concentrated, and of larger size than ordinary. Many of the flakes were more than $\frac{1}{4}$-inch in diameter.

Pieces of pegmatite composed of feldspar, blue quartz, and large pieces of graphite were also observed.

When the mine was worked for iron ore, the clay and graphite were separated from the limonite ore by means of log washers and thrown away. Attempts to separate the clay from the graphite in this waste material were made by the graphite company, but without success.

The mine was worked by means of a vertical shaft and a drift run out under the old iron ore pit at the 40-foot level. Ore from the open pit was thrown to the bottom where it fell into cars in the drift. The cars were trammed to the shaft and these elevated to the level of the top of the mill where they were pushed over a trestle to the ore bin.

A large flow of water was encountered in the bottom of the shaft which furnished sufficient water for concentration. The first stage in the process of concentration was accomplished by means of log washers which separated the masses of limonite ore from the clay and graphite. Later the ore passed through driers, pneumatic separators and buhrstone mills. The product was of good quality, but the ore containing sufficient graphite to be worked economically was limited in amount and the mine had to be abandoned. Altogether it probably produced about 500 tons of graphite during the entire time it was operated.

FEDERAL CARBON COMPANY.

The mine and mill of the Federal Carbon Company are located three-fourths mile southeast of Pikeland. The company is the successor of the Federal Graphite Company.

The mine was first opened several years prior to 1900 and abandoned. In the Mineral Industry for 1902 (pp. 347-348) the following description of the plant is given. "The Federal Graphite Co......... is equipping its plant with a magnetic concentrator of the roller type for the removal of the greater part of the ferruginous impurities,

the balance being extracted by a special treatment with hydrochloric acid. The material as it comes from the concentrator is added to an acid bath, agitated for four hours with live steam, and allowed to remain in the acid for 25 hours additional. It is then thoroughly washed to remove all traces of acid and dried, which yields a flake product stated to be equal in quality to the Ceylon chip graphite." The process was a failure.

In 1903 the mill was destroyed by fire, but was rebuilt during the same year. The mine was closed in July, 1905, and has not been operated since. In 1909 the company was reorganized under its present name, and would have been reopened but for the lack of water during that summer. In the fall of 1911 the water was pumped from the mine and a thorough examination was made of the mine and ore. Although the mill has been closed for several years the machinery and mine are in good condition so that the operations could be started at any time.

The ore is a bed of graphitic gneiss which was about 6 feet in thickness where observed underground, but which is stated to be much thicker in certain places. In the open cut it was about 30 feet thick. The bed has a fairly uniform southeasterly dip of about 30°. The strike is approximately N. 45° E.

The graphite-bearing rock is a rotten gneiss with thin bands suggesting a schist. It is composed of kaolinized feldspar, quartz, graphite, and much iron rust probably derived from pyrite or pyrrhotite. The flakes of graphite are of large size, most of them ¼-inch in diameter, and are arranged parallel to the banding.

Pegmatites cut the bed in many places and are, in general, parallel to the beds of gneiss. In one place a persistent pegmatite dike about 14 inches in thickness was long supposed to form the hanging wall but on breaking through it good graphite ore was found above it. The pegmatites carry considerable graphite in the form of foliated masses several inches in diameter composed of practically pure graphite, or in large thick flakes. The graphite of the pegmatites pulverizes readily in the crushers and rolls and the flakes are so thick that they do not float easily, consequently the pegmatites do not yield much graphite concentrate, regardless of the percentage of graphite they carry. Some of the pegmatites contain so much quartz that they are not essentially unlike quartz veins in composition. The gneiss adjoining the pegmatites carried a higher percentage of graphite and in larger flakes.

Besides the pegmatites the original rock has also been intruded by an acid granite gneiss composed almost entirely of orthoclase and quartz, with a few small flakes of graphite. The specimens obtained were in contact with the ore and probably picked up the carbon from the country rock; if so, the granite some distance away would

Fig. 1. Mill of Girard Graphite Company, Hallman.

Fig. 2. Mill of Federal Carbon Company, Pikeland.

Fig. 1. Open Pit of Federal Carbon Company, Pikeland.

Fig. 2. Mill of Crucible Flake Graphite Company, Chester Springs.

be expected to be free from graphite. This rock has undergone little decomposition and forms a striking contrast to the rotten graphitic gneiss. The absence of pyrite or pyrrhotite in the former is undoubtedly the explanation of the great difference.

The mine was first operated by an open cut along the graphite bed. The pit is about 400 feet long, 100 feet wide, and 40 feet deep. Later a vertical shaft was sunk 143 feet cutting the ore bed at the depth of 60 feet. At the depth of 55 feet a tunnel was driven to the northeast emerging from the side of the hill just above the mill. Ore from the open cut was milled down to the tunnel level and the ore from deeper levels hoisted to the same place whence it was hauled to the mill. At the 60-foot level drifts are run in the ore body about 200 feet in each direction. There is also at the same level a 100-foot drift to the west which was run to determine the thickness of the ore bed.

At the 143-foot level drifts were run in the ore body 250 feet to the northeast and 175 feet to the southwest. At this same level a short 50-foot drift was run to the south as a prospect. Very little stoping has been done so that a great body of ore has been blocked out ready for mining. The ore contains from 3% to 7% graphite.

In the mill the ore passes first through a jaw crusher and then to two series of log washers. The heads pass to eight reels and then to a cement floor where water is played on it and effects a still further concentration. Thence the heads pass through a float reel and then to a rotary kiln drier, 25 feet in length. From the drier the material passes through a reel, the heads passing to a buhrstone mill and the tails to rolls. It is further refined by passing through various bolting reels and the coarser material reground in buhrs.

CHESTER GRAPHITE COMPANY.

The mine and mill recently operated by the Chester Graphite Company are located about one mile southeast of Chester Springs.

The mine has passed through several hands and has been operated at several different times during the past 15 years. The mine was located and opened by the Philadelphia Graphite Company in 1896 and began to produce in the following year. In 1898 the company produced 700 tons of graphite concentrates, 800 tons in 1899, 600 tons in 1900, and 600 tons in 1901. During the latter year the property was sold to other parties who operated it during 1902 under the same name. In 1903 it was again sold to certain people who organized the New Philadelphia Graphite Company. This company was soon succeeded by the Keystone Graphite Company which in turn leased the property to the Chester Graphite Company in 1907. This latter company worked the mine and mill until the fall of 1910, when it gave up the lease, since which time the property has been idle.

The ore body is a continuation of that of the Federal Carbon Company whose property adjoins it on the east. The bed of ore is about 20 feet in thickness, but varies somewhat by pinching and swelling. It dips to the southeast at an angle of about 35° with a strike of about N. 25° E.

The rock is greatly decomposed and consists of kaolinized feldspar, quartz, and graphite with a small amount of mica. The rock is less schistose than in the mine of the Federal Carbon Company. The ore averages about 3% graphite at present. One of the early operators of the mine claims that the ore worked by him ran 20% to 25% concentrates.

The rock has been intruded by many pegmatite dikes that contain large flakes of graphite and occasional nests of foliated graphite. One such mass of graphite collected is about three inches in diameter and is composed of foliated graphite showing marked radiating structure. These masses of pure graphite are found in association with large pieces of white quartz.

Although there is a shaft 225 feet in depth, the ore has been mainly worked by open cut. There are two of these open cuts on the hill-side above the mill. One of the cuts is about 300 feet in length along the strike and the other about 100 feet.

A tunnel has been run from the level of the upper part of the mill into the hill for a distance of about 400 feet. Openings have been made connecting the tunnel with the open pits and ore from the pits is wheeled in wheelbarrows to these openings where it is thrown down into cars in the tunnel. The ore is then trammed to the mill. The ore is so greatly decomposed that it can be worked by means of pick and shovel with ease.

Water for concentration is pumped from the creek nearby. The method of concentration employed has been described in the chapter on "Concentration" and the flow sheet reproduced.

In the fall of 1910 the Chester Graphite Company surrendered its lease on the mine and mill and has since confined their activities to the refining of graphite and the manufacture of lubricants and other graphite products. The company owns the land adjoining on the west the property previously leased and has proved by means of numerous test pits that the ore body continues through their land with only a slight change in the strike.

The mill where the company carries on its refining and manufacturing is conveniently located near a stream that furnishes considerable water power.

Views of Graphite Gneiss in Open Pit of Chester Graphite Company, Chester Springs.

CONSOLIDATED GRAPHITE COMPANY.

The property of this company is located about three-eighths of a mile south of the railroad, about midway between Chester Springs and Anselma.

Considerable prospecting has been done and good graphite ore is reported to have been found. No mining has been done yet but the company hopes to develop a mine and build a mill.

ANSELMA GRAPHITE COMPANY.

The mine and mill of this company are located about one-fourth mile east of the little village of Anselma and about three-fourths mile southeast of Anselma Station. The company was organized as the National Graphite Company but a few years ago in a reorganization the name was changed to the Anselma Graphite Company.

The National Graphite Company was incorporated under the laws of New Jersey in March, 1905, with a capitalization of $150,000. The mine was opened near the top of the hill and a mill erected nearby. During 1906 the mill was run about two months, since which time it has been idle and is now partially dismantled. In 1910, under a new management, a tunnel was started into the hill at a lower level, the plan being to continue it until it cut the ore bed, but it was soon abandoned.

The ore bed dips to the south at an angle of 45° with a strike of N. 80° E. and is about 8 feet in thickness. This bed has not been worked elsewhere in the district. The ore averages about 3% graphite.

The ore differs from that exposed in any of the other mines of the region in that it contains a greater amount of quartz which has not fallen apart on the decomposition of the feldspar but remains as a hard, porous quartz rock containing graphite, in which the kaolin has in many places been largely removed. The original rock was composed of feldspar, quartz and graphite with probably some pyrite or pyrrhotite as indicated by the iron stains through the ore. It now consists of quartz, both blue and white, kaolin, and large flakes of graphite. By removal of the kaolin the rock has been rendered porous in places and the flakes of graphite now extend into those cavities. In other places there has been deposition of secondary quartz in lenses an inch or more in thickness. The rock shows some banding.

The ore was worked by means of a slope driven on the foot wall with drifts extending both east and west at a depth of 50 feet. Also some ore was mined in open cut. The slope is now filled with water preventing the examination of the deeper workings.

The mill was equipped with the usual machinery most of which has now been removed. When the mill was first started there was a

roaster for first roasting the ore in order that the quartz might be more easily crushed. Difficulty was experienced in separating the graphite from the gangue. Fine grinding was necessary to separate the graphite from the firm quartz in which it was contained, and in the process of grinding the graphite flakes were cut into small dust particles. Also dry concentration was not successful, and the only supply of water available, that pumped from the mine, was insufficient.

PICKERING VALLEY GRAPHITE COMPANY.

The Pickering Valley Graphite Company has for several years had a lease on the farm of J. H. Dewees, one-half mile west of Lionvile. A shallow shaft was sunk and a tunnel driven into the side of the hill, but while graphitic gneiss was found it seems that the company considered it of too low grade to be profitably worked.

PETTINOS BROTHERS GRAPHITE MINE.

The first graphite mine opened in the Pickering Valley is on the property now belonging to Pettinos Brothers and located one-half mile southeast of Byers (Uwchland P. O.) It was first known as the Phoenix Mine and was opened in the late '70's. In 1895 the property was leased by its present owners and later bought by them. For 4 years the mine was operated almost continuously with an average production of 3 to 4 tons of concentrates a day. The mill burned in 1899 but was soon rebuilt. During the past 10 years the mine and mills have been operated only a part of the time. It was operated almost continuously during 1911 and work will be resumed in the Spring of 1912. The ore is concentrated in the mill located near the mine and then shipped to the refining mill of the same company at Bethlehem.

Mining has been done both by open cut and underground work. There is a shaft 98 feet in depth with two drifts running off from the bottom, one of which is 125 feet in length, the other 75 feet. The ore in the drifts is hard and contains much pyrite or marcasite which has been oxidized and leached from the ore near the surface. No underground work has been done for about 10 years. There are many shallow pits on the property.

The ore varies from a graphitic gneiss that seems to be practically free from calcite to a calcareous gneiss, while on the adjoining property of the Pennsylvania Graphite Company a coarse-grained crystalline limestone containing graphite and other metamorphic minerals is well represented. The rock is greatly weathered and near the surface all of the calcareous material has been removed.

The rock is composed of gray kaolinized orthoclase, slightly bluish quartz, graphite flakes $\frac{1}{4}$-inch in diameter, a small amount of biotite,

Fig. 1. Mill of Anselma Graphite Company, Anselma.

Fig. 2. Concentrating Mill of Pettinos Bros., Byers.

and much pyrite and marcasite. Some of the fresher pieces of rock show the presence of calcareous matter by slight effervescence when treated with hydrochloric acid.

In the main, the decomposed rock consists of kaolin, quartz, graphite and mica with yellow or brown iron stains. This loose earthy material is so thoroughly disintegrated that it requires practically no crushing. The iron sulphide present has been largely oxidized to form the sulphate which has been removed by percolating waters. Some of it has been converted to limonite and segregated in masses of fairly good brown iron ore in which there are numerous flakes of graphite and considerable siliceous matter.

Some rock from the shaft that has been lying on the dump for several years contains much ferrous sulphate formed from the marcasite or pyrite. The shaft is full of water and no ore has been taken from it for several years, but it is said that the ore at the lower level was hard and fresh but readily crumbled when thrown on the dump for a few months or years because of the marcasite present.

PENNSYLVANIA GRAPHITE COMPANY.

The mine and mill of the Pennsylvania Graphite Company are located one-fourth mile south of Byers (Uwchland P. O.) The property adjoins that of Pettinos Brothers on the West.

The history of the mine is complicated, as it has changed hands so many different times. It was first opened by the Pennsylvania Graphite Company in the middle '70's. There is a record of some graphite from this mine having been sold to the Gautier Company of Jersey City in 1876. In 1880 it was the only operating graphite company in the State and produced in that year 440 tons of concentrates valued at $24,000. Twenty-eight men were employed in the mill and 12 in the mine. About this time the name seems to have been changed to the Pennsylvania Graphite Mining and Manufacturing Company.

In 1881 the property was sold for $50,000 and the name changed to the Pennsylvania Plumbago Company. The purchaser failing to make a success of the mine brought suit for the recovery of his purchase money in 1888 and was awarded $39,390.

In 1889 the American Plumbago Company, owning the adjoining property belonging to Pettinos Bros., leased a portion of the John Tod farm and worked one of the old open cuts now located in the east part of the Pennsylvania property. They soon surrendered the lease and somewhat later Bullit, Edmonds and McIntyre bought the property and put up a mill which in remodelled form still stands. They worked the mine for several years. This firm sank the slope and began to work the ore by underground methods.

In 1903 the property was bought by Mr. John P. MacLearn who organized a new company called the Pennsylvania Graphite Company. It was operated by this company until June 20, 1904, when it was leased to the United States Graphite Company on the favorable terms of $1500 a month rental and 10% royalty on amount realized on sales. This company which was capitalized at $600,000 carried on an active publicity campaign in which gross mis-statements were made. One report to the stockholders contains the following sentences: "The Company has recently struck one of the most valuable veins of graphite ever opened in the country. Its average is nearly 50% of pure mineral, and is being taken out in large quantities." A large and expensive 3-story refining mill 50 x 100 feet of cement, brick and frame construction, was built near the railroad and partially equipped. Two and one-half per cent. quarterly dividends were paid for about two years.

In the fall of 1907 the company ceased operations and soon after suit was brought against some of the officers of the company by certain stockholders who claimed that $590,000 belonging to the company had been misappropriated. Three of the men were convicted and given jail sentences and the property was sold at auction on May 7, 1908.

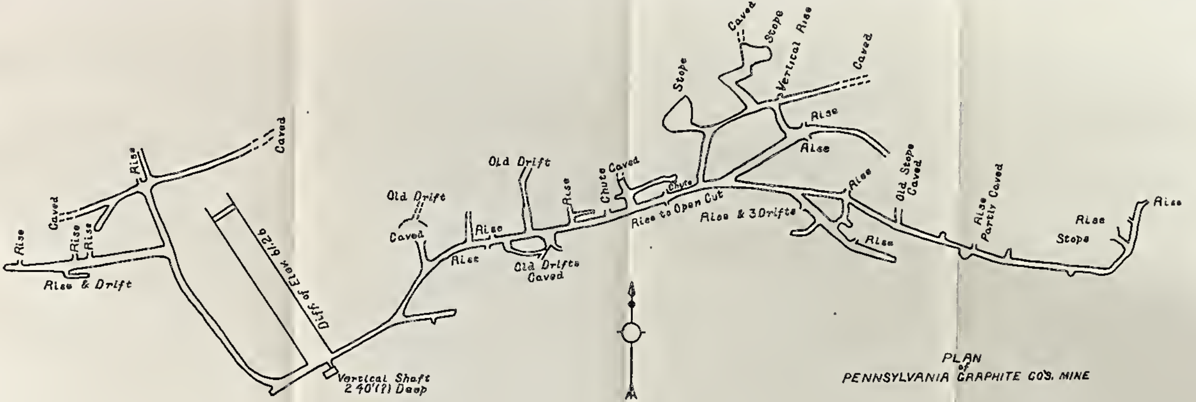
In the summer of 1908 the lease of the Pennsylvania Mine and old mill to the United States Graphite Company was annulled for non-payment of rental. About the same time (August, 1908) an injunction was issued restraining the United States Graphite Company from using the name on account of the previous use of that name by a company in Saginaw, Michigan. Accordingly a new company, the Imperial Graphite Company, was incorporated in New Jersey for $600,000, which took over the property of the old United States Graphite Company, consisting of the new mill and some land. The further history of the company will be considered in connection with the description of the Eynon-Just Graphite Company, the successor of the Imperial Graphite Company.

In June, 1910, the mine and mill of the Pennsylvania Graphite Company were sold to the recently organized Acme Graphite Company, which company had previously purchased the Continental Mine nearby. The mine was worked part of the time during the summer and fall of 1910 but was closed in December of that year. The property has been idle since that time. On Oct. 19, 1911, the Pennsylvania Graphite Company again took possession and has since been keeping a man at the mine to keep the water pumped out.

The ore of the Pennsylvania Graphite Company's mine varies from a calcareous gneiss to a coarsely crystalline limestone containing many metamorphic minerals. Near the surface the calcareous matter has been largely removed and the ore consists of iron-stained kaolin,

Fig. 1. Mill of Pennsylvania Graphite Company, Byers.

Fig. 2. Open Pits at Mine of Pennsylvania Graphite Company, Byers.


Caved
Rise
Rise
Caved
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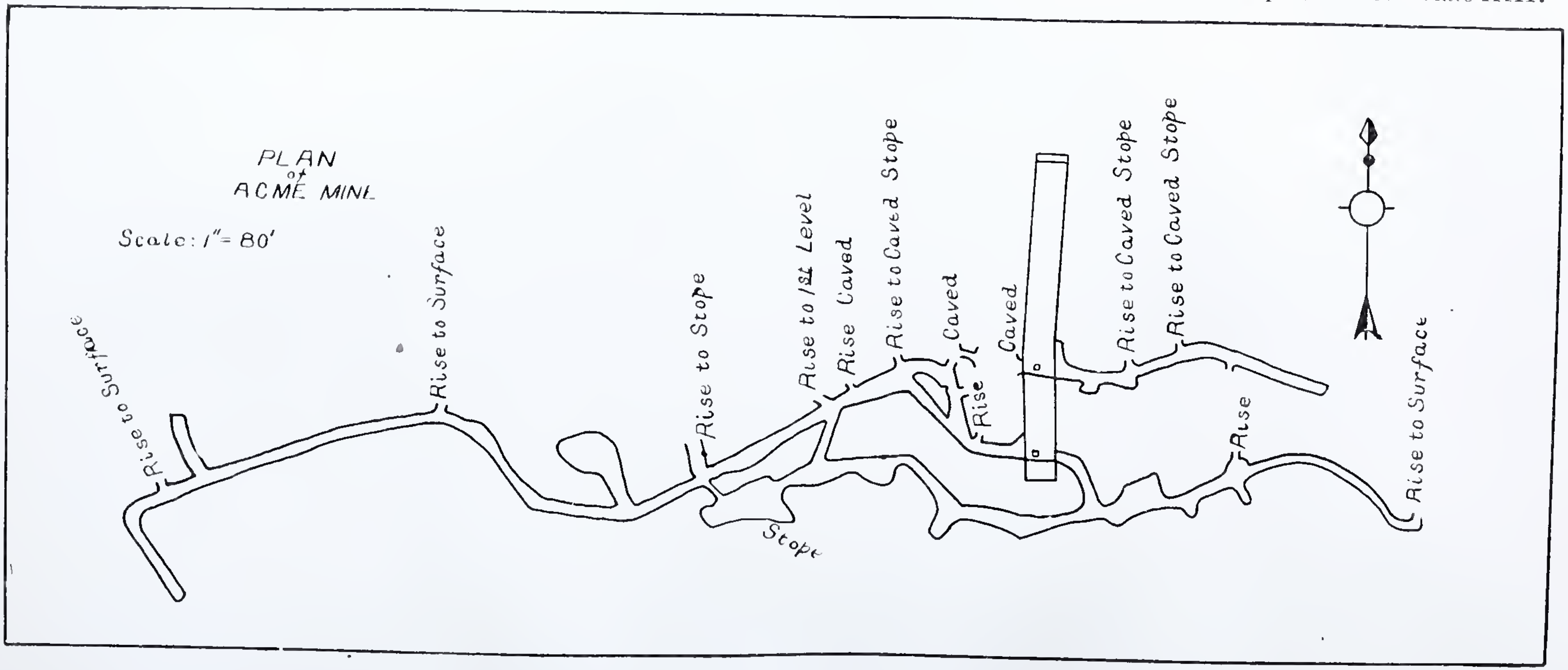
Rise
Rise & Drift
Diff of Elev 91.6
Vertical Shaft
240'(?) Deep
Old Drift
Caved
Rise
Rise
Old Drift
Old Drifts
Caved
Rise
Chute
Caved
Chute
Rise to Open Cut
Rise & 3 Drifts
Stope
Caved
Stope
Vertical Rise
Caved
Rise
Rise
Rise
Rise
Old Stope
Caved
Rise
Partly Caved
Rise
Stope
Rise
PLAN
of
PENNSYLVANIA GRAPHITE CO'S. MINE
Scale 1" = 80'


PLAN
of
ACME MINE
Scale: 1" = 80'
Rise to Surface
Rise to Surface
Rise to Stope
Stope
Rise to 1st Level
Rise Caved
Rise to Caved Stope
Caved
Rise
Caved
Rise to Caved Stope
Rise to Caved Stope
Rise
Rise to Surface

quartz, graphite, and a small amount of biotite. In a few places in the open cuts the graphite is found in a matrix of a bright greenish-yellow color that seems to be chloropal. In the deeper portions of the mine where weathering has not progressed so far, altered crystalline limestones occur in which there is much graphite in large flakes showing no orderly arrangement in association with calcite, quartz, wernerite, biotite, diopside, epidote, tremolite, garnet, zoisite and titanite. The biotite is concentrated in certain beds, others being practically free from it. Some vugs were observed filled with sharp-pointed scalenohedral crystals of calcite.

Pegmatites are common and contain large masses of blue quartz, foliated graphite, feldspar and secondary calcite, with small amounts of allanite, augite, pyrite, titanite and zircon. In some pegmatites the graphite is irregularly distributed throughout but in others the graphite occurs only in the peripheries, showing quite conclusively that it has been picked up from the country rock.

The pegmatite dikes are, in general, parallel to the enclosing beds, although some were observed to cut the beds of calcareous gneiss at low angles. Much of the graphite of the pegmatites is lost because of the thickness of the flakes which causes them to sink with the quartz and kaolin in the flotation method of concentration.

One dike of fine-grained granite was observed that had undergone little decomposition. It contained plagioclase, orthoclase, pyrite, biotite, quartz, and zircon but no graphite. Some granite gneiss contains many garnets, but is particularly barren of graphite.

The ore beds dip to the south at an angle of about 40° with a strike N. 80° W. They have been displaced by faults in several places and slickensided surfaces are common throughout the mine. There seem to be three workable beds which are roughly parallel and all vary greatly in thickness, from a few inches to 20 feet or more. In general, the thickness of the beds, rich enough to pay for working, is about 10 feet. Pegmatites are very abundant and the ore bed, in places, owes its great thickness to the pegmatites which follow the bedding of the rock. Little or no graphite is found in the pegmatites. The ore contains from 4% to 8% of graphite with an average of about 6½% to 7% according to statements of those persons most familiar with the property.

The greater amount of mining has been by open cut and there are several of these cuts on the property. The largest of these is about 400 feet in length along the strike of the ore bed and about 30 feet in depth.

In recent years most of the ore has been taken out through an inclined slope which follows the dip of the bed. The bottom of the slope is 61 feet from the surface and is near a vertical two-compartment shaft 240 feet in depth. The shaft is filled with water to the

level of the bottom of the slope, and has never been used. Drifts are run in either direction at the 61-foot level and stopes raised at occasional intervals as shown on the accompanying survey of the underground workings. Some of the stopes have been carried up to the open cuts. Considerable timbering is necessary, due to the decayed character of the ore. When the ore is lost because of faulting drifts are run in either the foot wall or hanging wall to locate the displaced ore bed.

The ore is mainly so soft that it can be broken in the hand and is crushed in rolls. The harder pieces are passed through a Blake crusher. The ore then goes to a hexagonal shaft agitator making 1,400 revolutions per minute, where much of the graphite is freed from the clayey gangue. Thence the ore goes through log washers and reels. It is dried in a rotary kiln where any wood particles present are burned and the biotite is rendered brittle enough to be easily pulverized in the rolls and buhrstone mills.

The further system of refining the graphite is by repeated grinding and bolting through reels covered with screens of various sized mesh.

ACME GRAPHITE COMPANY.

The mine and mill of the Acme Graphite Company are located one-half mile west of Byers (Uwchland P. O.) As early as 1882 an attempt was made to mine graphite on the adjoining property by the Eagle Plumbago Company, but it seems that little work was done. The ore was hauled to a concentrating mill near Lionville.

In 1906 the Continental Graphite Company was organized and incorporated under the laws of New Jersey with a capital of $550,000. During the same year a mill was constructed. In 1909 the company discontinued operations and passed into the hands of the Acme Graphite Company which had been recently organized. Under the new company, work was again started and continued until December, 1910. Since then the property has been idle. It was recently sold to John C. Hill of New York, but retains the name of the Acme Graphite Company.

The ore is similar to that occurring in the Pennsylvania mine with the exception that the ore body seems to be less persistent. Although the two mines are close together the beds are probably not continuous. Coarse crystalline limestone, calcareous gneiss, and non-calcareous gneiss carry the graphite, although the limestone is of little importance. There are also some lenses, or beds, of sericitic quartz schist in which there is little or no graphite. The ore is less decomposed than in most of the graphite mines of the district.

Much of the crystalline limestone has undergone great alteration during metamorphism and contains much wernerite, chlorite and anthophyllite?

Fig. 1. Concentrating Mill of Acme Graphite Company, Byers.

Fig. 2. Head-frame and Covered Tram-way at Mine of Acme Graphite Company, Byers.

Calcareous gneiss composed of bluish quartz, kaolinized feldspar, praphite, and some biotite and showing decided bands, constitute the principal ore. It occurs in a bed of somewhat variable thickness from 10 to 30 feet. The beds dip 45° S. Some of them contain much yellowish colored chlorite and anthophyllite. In some places the kaolin has been largely replaced by secondary quartz and the ore consists almost entirely of quartz and graphite with some pyrite. The graphite is concentrated in bands with the flakes arranged parallel as in the ordinary gneiss. Near the surface some of the iron from the pyrite has been altered and the iron segregated as siliceous limonitic iron ore enclosing many graphite flakes.

The mine is worked by an inclined slope with drifts running in both directions along the bed as shown in the accompanying survey of the underground workings.

The method of concentration used by the company has been described in the chapter on "Concentration."

ROCK GRAPHITE MINING AND MANUFACTURING COMPANY.

The property of this company, consisting of a mine and mill, is located one mile northwest of Chester Springs. The mill is located several hundred yards from the mine pit that furnishes the ore.

The property was purchased in 1904 by the Sterling Graphite Company which began the erection of a mill in 1906. The mill was completed and operations started during the latter part of October, 1907. It has been operated intermittently ever since. In 1910 the property was sold to the present company.

The ore is a fine-grained gneiss, distinctly banded, composed of orthoclase, plagioclase, quartz, graphite, pyrrhotite, and biotite. The ore has undergone little decomposition and is thus decidedly unlike the other graphite ores of the district which have decayed to such an extent as to permit them to be crumbled in the hand. The abundance of pyrrhotite also distinguishes this ore from the other ores in the valley. The graphite flakes show a marked parallel arrangement and vary in size from 1-16 to 1-8 inch in diameter.

Pegmatite dikes are numerous and are composed of large pieces of blue quartz, greenish-yellow plagioclase, graphite, and pyrrhotite. Some masses of solid pyrrhotite 5 inches in diameter were noticed. In the accompanying microphotograph the light colored minerals are plagioclase and quartz, the large black masses are pyrrhotite, and the lath-shaped crystals are graphite.

The graphite rock dips almost due east at an angle of 32° with a north-south strike, approximately at a right angle to the strike of the graphite beds outcropping on the south side of the railroad.

The ore is worked in an open pit on the northeast side of the hill several hundred feet from the mill. The quarry is about 100 feet

wide and 40 feet deep in one place. A thickness of about 30 feet of graphite rock is exposed, containing slightly more than 3% graphite. Formerly some ore was obtained from a pit nearer the mill where there is a superabundance of pegmatite ore. Ore is trammed to the mill where it is concentrated by a combined dry and wet process. The ore goes first to a jaw crusher and then to a rotary kiln drier, thence to rolls, and a pneumatic separator which separates the fine dust from the coarser particles. The latter pass through 2 log washers and then to reels. The concentrates go to another rotary kiln drier and thence to flour mill rolls and bolting reels.

CRUCIBLE FLAKE GRAPHITE COMPANY.

The quarry and mill of the Crucible Flake Graphite Company are located one mile northwest of Chester Springs, adjoining the property of the Rock Graphite Mining and Manufacturing Company.

This company, locally known as the Parker Graphite Company, because of the president and chief promoter, Mayne C. P. Parker, was incorporated under the laws of the State of Delaware in 1905, with a capital of $300,000. It began the erection of a mill in 1906.

Altogether little work has been done since the mill was completed and the stockholders in the company have lost heavily. The mill has recently been partially dismantled.

The ore is practically the same as that on the adjoining property described above but there is only a small amount of good ore in sight. The quarry is located near the top of a hill and is connected with the mill by a tramway which passes through a tunnel for the greater portion of the distance.

The ore has a dip of 38° E. with a strike approximately due north and south.

The pegmatites contain some large masses of graphite especially near the contact with the country rock.

The mill was equipped with expensive machinery similar to that used by the Rock Graphite Mining and Manufacturing Company except that electric power was used.

THE EYNON-JUST COMPANY.

The main plant of the Eynon-Just Company is located ¼-mile southeast of Coventryville in the valley of French Creek. The mine and concentrating mill are there while the refining mill is located ⅛ mile south of Byers (Uwchland P. O.)

The company is the successor of the Imperial Graphite Company which was in turn the successor of the United States Graphite Company as stated in the description of the Pennsylvania Graphite Company given on a preceding page. After the Pennsylvania mine re-

Fig. 1. Gangway in Mine of Acme Graphite Company, Byers.

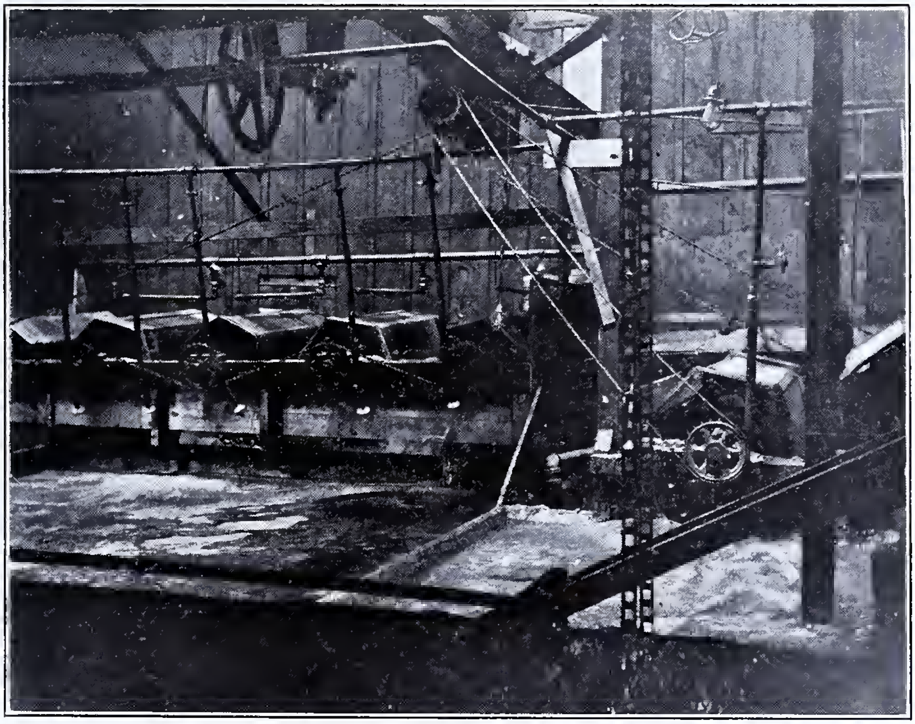


Fig. 2. Interior View, Acme Graphite Company's Mill, Byers, Showing Reels.

verted to its former owners the United States Graphite Company was left with a fine mill but no mine. Property was finally purchased near Coventryville about 9 miles north of Byers and a mine opened. A mill was later built near the mine for concentrating the ore, while the concentrates are hauled to Byers by wagon for further refining of the flake. At present this is the most active graphite mining company in the district.

The rock is a banded graphite gneiss composed of partially kaolinized feldspar, graphite flakes 1-16 to ⅛ inch in diameter arranged parallel to the bands in the gneiss, some biotite, and small amounts of pyrite. The rock has undergone less decomposition than most of the graphitic gneiss of the county.

The ore bed is about 10 feet in thickness and dips to the north at an angle varying between 30° and 45°.

A few pegmatite dikes cut the gneiss. They are composed of blue quartz, orthoclase, and graphite.

Franklin limestone has been quarried near the graphite mine but no calcite was observed in the gneiss.

The workings consist of two small open cuts in the side of the hill and about 200 feet of drifts run on the level of the mill with small prospect stopes and a 70-foot shaft.

The ore is concentrated by means of crushers, rolls, classifiers, log-washers and reels.

GRAPHITE MINES OF BERKS COUNTY.

Graphitic gneiss is widely distributed in the crystalline rocks of South Mountain, or Reading Hills, and several graphite mines and prospects have been worked in the eastern portion of the county. All of them were unsuccessful, however, for one reason or another, and no graphite mines have been operated in this county for several years. The mines are located in two regions, near Boyertown and in the vicinity of Rittenhouse Gap.

BOYERTOWN GRAPHITE COMPANY.

The mine of this company is located one mile northwest of Boyertown, a short distance north of the Reading-Boyertown electric line.

The mine was first opened between 1875 and 1880 and operated for a short time. In 1899 it was reopened and a concentrating mill was erected. In 1905 the mine passed into the hands of the Columbia Graphite Company and was again worked for a short time.

The rock is a fine-grained graphite gneiss with marked lamination, composed of kaolinized feldspar, quartz, graphite, and biotite. The graphite flakes are small in the specimens observed about the mine shaft, few being larger than ¼-inch in diameter and most of them much

smaller. They were dull in appearance and friable. Through shearing action some of the graphite flakes have been compressed to form matted sheets of fibrous and foliated graphite. The graphite content of the rock is larger than in much of the graphite gneiss of the State, probably averaging 7% to 10% carbon, although no analyses are available. Mica is relatively abundant.

Some vein quartz and pegmatites containing graphite occur in the gneiss as shown by the fragments about the mill. Some pyrite is present in the pegmatite.

The mine was worked by means of a shaft which is said to be 125 feet in depth which was partly filled with water at the time of our visit. The graphite-bearing bed is reported to have been 15 feet in width. The ore was hoisted by means of a windlass and taken by wheelbarrow to the mill nearby for concentration. The mill was rather elaborately equipped but much of the machinery has now been removed.

Much difficulty was encountered in cleaning the flake on account of the mica present and by the appearance of the material on the waste heap it seems that much of the graphite was lost. The mine was abandoned for this reason and has now been idle for several years.

Graphite is also reported to have been dug at "Dr. Funk's fish dam" about one-half mile west of Boyertown.

PENN GRAPHITE COMPANY.

The mine of this company is located in the northeastern portion of Berks county, about three-fourths mile south of Mertztown and one mile southwest of Longswamp.

The mine was first opened between 1880 and 1890 and was called the Riley mine. Little work seems to have been done, however, until 1897, when the Penn Graphite Company was organized to work it. A mill was erected and the mine was operated for several years but it was never a paying proposition according to reports. In 1901 the Company is reported to have produced 1½ tons of good flake and ½ ton of lower grade material per day. The mine was closed in 1901 and has not been operated since.

The graphite has been reported to occur "in a lenticular vein in a coarse grained sandstone,"* and this statement has been quoted in several later publications. Cambrian quartzite does outcrop in the near vicinity of the mine but it does not contain graphite. The graphite forms a prominent constituent of a greatly decayed acid gneiss in which the feldspar has been thoroughly kaolinized. Much quartz is present. Some of the kaolin is decidedly pink in color,

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*Hopkins: Mines and Minerals, Vol. 21, p. 352.

Fig. 1. Mill of Rock Graphite Mining and Manufacturing Company, Chester Springs.

Fig. 2. Micro-photograph of Graphitic Gneiss from Quarry of Rock Graphite Mining and Manufacturing Company, Chester Springs.
(The light colored minerals are plagioclase and quartz, the large black masses are pyrrhotite, and the lath-shaped minerals are graphite.)

probably due to iron stain. The great amount of iron rust suggests the former presence of pyrite which has now been oxidized. Mica was not observed in the few specimens obtained about the mine.

The graphite flakes are seldom seen as distinct and separate particles regularly disseminated through the rock but, in the main, are matted together in irregular curved sheets. The rock has undoubtedly been sheared a great deal after the coherence of the mineral particles was overcome during decomposition and in the shearing process the graphite flakes were compressed in the irregular sheets. The graphite seems to be unusually friable and it is doubtful whether large flake concentrates could be obtained. The ore bed is said* to have been a lenticular vein with a maximum thickness of 39 feet with 28% of the vein material graphite. Certainly the average ore did not contain that amount of graphite, judging from the ore specimens found about the mine and mill. It is probable that the ore contained considerably less than 7%, although no figures to verify such a conclusion are available.

The mine was worked by a 90-foot shaft from which drifts were run at different levels. The rotten character of the rock enabled the miners to remove the rock by means of pick and shovel alone. The ore was hoisted to the surface by horse power and concentrated in a well-equipped mill. The waste sand was sold to foundrymen for moulding purposes. The machinery has now been removed and the mill is in ruins.

BITTENBENDER IRON MINE.

Graphite occurs in gneiss and Franklin limestone at the Bittenbender Iron Mine, one-half mile northeast of Seisholtzville. The mine has furnished a large amount of high-grade magnetite ore but has not been operated for several years. No graphite has ever been mined at this place but its abundant and varied occurrence warrants a brief description. It furnishes another illustration of the intimate connection existing between the Franklin Limestone and the graphitic gneiss of Pennsylvania.

No observations could be made of the various graphite bearing rocks in place and the following information was obtained through a study of the rocks on the waste heaps near the mine opening.

Many specimens of white crystalline limestone with flakes of graphite $\frac{1}{4}$-inch in diameter, irregularly disseminated, were seen on these waste heaps. The flakes show no regularity of arrangement. Some of the limestones seem to have been altered to silicated rocks with segregations of augite, graphite, and an asbestiform mineral.

Other rocks consist of dark red garnet, hornblende, augite, and graphite. Specimens of massive magnetite were observed in which

*loc. cit. p. 352.

there were occasional partings of graphite. Some of the rocks consist of massive hornblende, augite, some hypersthene, and graphite flakes. Gneiss such as occurs in other graphite areas is also present in which the mass of the rock is composed of plagioclase, quartz, augite, and flakes of graphite $\frac{1}{8}$-inch in diameter. Pegmatites composed of orthoclase, quartz and large graphite flakes are represented by occasional specimens.

In no other place in the State is there such a variety of graphitic rocks so that it is especially unfortunate that their relations are not known. It is improbable that any of them could ever be profitably worked for graphite.

IRON MINE PROSPECT, ONE MILE SOUTH OF SEISHOLTZVILLE.

At this place there is a dark-colored banded gneiss composed of feldspar, quartz, hornblende, biotite, magnetite, garnet, pyrite and graphite. Some specimens of mica schist were seen on the rock heap and many pieces of massive magnetite.

GRAPHITE PROSPECT AT HARLEM.

About 10 years ago a prospect hole was sunk about 15 feet in depth on the farm of Nathaniel Gregory at Harlem, in search of a workable deposit of graphite. Considerable water was encountered and the project was abandoned.

Some fragments of graphitic gneiss, picked up near the old opening, contain much orthoclase and quartz with smaller amounts of graphite and biotite. The graphite occurs in small disseminated flakes and in sheeted masses. The feldspar is greatly decomposed and much of the graphite exceedingly friable.

Similar material was found in digging a 30-foot well on the farm of A. M. Trollinger, one-half mile west of Harlem.

GRAPHITE PROSPECTS ONE AND ONE-HALF MILES SOUTHWEST OF RITTENHOUSE GAP.

One and one-half miles southwest of Rittenhouse Gap, on the farm of Peter Smith, several pits and shafts have been dug in prospecting for graphite. Several different parties have held leases on the property at various times and have conducted investigations to determine the character and extent of the graphite ore but no attempts have been made to open a mine. Some of the prospect shafts are 35 feet in depth.

The graphite forms part of a rotten graphitic acid gneiss in which the feldspar has been almost entirely changed to kaolin. Both orthoclase and plagioclase occur in the rock with much quartz and smaller amounts of graphite, biotite, and pyrite. The flakes are unusually large, probably $\frac{1}{8}$-inch in diameter on the average, and are roughly parallel to the banding of the gneiss.

Fig. 1. Mill of Eynon-Just Graphite Company, Coventryville.

Fig. 2. Refining Mill of Eynon-Just Graphite Company, Byers.

Pegmatites, composed of quartz, feldspar, and large flakes of graphite, some once inch in diameter, are abundant. In some of the pegmatites the graphite is enclosed within the quartz and the flakes are sharply bent as though first formed about some quartz crystal which later grew by addition of more quartz and so enclosed the graphite.

The graphite possesses good physical characteristics. The average specimens observed probably contain more than 3% of graphite, although no analyses are available. In order to obtain the average percentage it would be necessary to make many analyses because of the variations in the ore. There is enough biotite present to cause considerable difficulty in the cleaning of the graphite.

GRAPHITE PROSPECT TWO MILES SOUTHWEST OF LONGSWAMP.

On the farm of Franklin DeLong, two miles southwest of Longswamp a prospect hole about 20 feet in depth was dug several years ago in searching for graphite. The ore found is similar to that described above. The feldspar is decomposed; pyrite probably originally present has decomposed leaving iron stains; biotite is present in small amounts; and the graphite in rather large flakes is arranged parallel to the gneiss bands.

GRAPHITE PROSPECT TWO MILES SOUTH OF LONGSWAMP.

On the farm of Charles Brensinger, two miles south of Longswamp, several holes were dug in a graphitic gneiss about 10 years ago. The rock is similar to that described above except that it is somewhat finer grained.

GRAPHITE MINES OF LEHIGH COUNTY.

Graphite occurs in several places in the metamorphic gneisses of South Mountain in the southeastern corner of Lehigh county but has never been worked with profit. Considerable development work has been done in two localities, but so far as known no attempt was ever made to concentrate the graphite.

BACKENSTOE GRAPHITE MINE.

The mine is located about one mile east of Vera Cruz Station and one mile west of Limeport, on the north side of the road connecting the two places. The history of the mine is somewhat indefinite but information obtained from different sources indicates that it was first opened more than 50 years ago as a gold and pyrite mine. The large amount of pyrite occurring in the graphite ore probably contains some gold. It is said that many men in the vicinity lost money in the venture.

Between 1890 and 1900 it was reopened as a graphite mine and work was carried on for about two months. A few years ago the

property was purchased by the Schuylkill Stone Co. of Philadelphia, and the tunnel was again cleaned out but no further work done.

The development work consists of a shaft about 35 feet in depth, located near the top of the hill and a tunnel about 150 feet in length that extends into the hill at a lower level.

There are no exposures of the graphite rock near the mine and the shaft and tunnel could not be entered. The loose pieces of rock obtained from the tunnel and shaft, however, probably represent the true character of the rock fairly well.

The rock is a graphitic gneiss composed mainly of kaolinized orthoclase, with some perthite, white quartz, pyrite, graphite, biotite, hornblende, and an asbestiform mineral. Many specimens show a distinct augen or lens structure, the pyrite especially occurring in small lenses about ½-inch in diameter, about which the graphite flakes are curved.

The graphite flakes are friable, probably due to weathering, and some of the graphite even appears to be amorphous. Many of the larger flakes are iridescent.

Much of the rock seems to have been sheared and the flakes of graphite overlap forming streaks of matted graphite flakes extending through the rock in bands or streaks.

Pegmatites are present and contain large flakes of graphite irregularly disseminated throughout the rock.

It is doubtful whether the mine would yield a good quality of graphito flake. Biotite, while relatively abundant in some specimens, is practically absent in most of the rock and would not be a serious handicap. Nothing is known of the thickness and extent of the graphite-bearing bed.

GRAPHITE PROSPECTS ON FARM OF JOHN WRIGHT.

On the farm of John Wright, one mile east of Emaus, on the top of South Mountain, some prospect pits were dug about 15 years ago. No information is now available concerning the amount of work done, the structure of the rock, and the thickness of the graphite-bearing bed. No outcrops of the graphite gneiss could be found in the immediate vicinity of the pits.

The rock in which the graphite occurs is an acid gneiss containing both plagioclase and orthoclase, the plagioclase predominant, blue quartz, considerable pyrite in small isolated grains, graphite, and biotite. The plagioclase is greenish-gray in color. The gneiss is indistinctly banded and the graphite flakes show little indication of parallelism of arrangement. In some of the rock the graphite flakes cut into each other. The flakes are of fair size, up to ½-inch in diameter and are tough and bright. Iridescence was observed in

some of the flakes. The presence of the biotite is said to have discouraged the men who were engaged in prospecting the property and operations were discontinued.

Across the road to the east, on an adjoining farm, a prospect pit was also dug, but it has now been filled and only a few pieces of the weathered rock remain about the opening. These seem to indicate the presence of similar rock to that occurring on the John Wright farm.

GRAPHITE MINES OF BUCKS COUNTY.

Graphite occurs in several places in the narrow band of crystalline rocks that extends across the southern portion of the county from Morrisville through Langhorne to Trevose. The graphite is found in a graphitic gneiss mainly but in one place it is present in the coarse-grained crystalline Franklin limestone. The graphitic gneiss and Franklin limestone seem to be closely related as discussed on an earlier page and there is little question but that they are contemporaneous.

Graphite has been mined at two places in Bucks county, in both places in the graphite gneiss.

GRAPHITE MINE NEAR TREVOSE.

The oldest graphite mine in Pennsylvania is located about three-fourths mile north of Trevose. The mine is said to have been opened about 1750 and soon abandoned. About 100 years later it was re-opened but it seems that it was found unprofitable to work it and it was soon abandoned again. A shaft of unknown depth was sunk but altogether it seems that little work was done.

No information in regard to the extent of the graphite-bearing bed and its characteristics is available. Some rock fragments found near the mouth of the old shaft show two methods of occurrence of the graphite; (1) disseminated flakes throughout the gneiss, (2) veins of graphite filling fissures in the rock.

The graphite of the first class occurs in two different kinds of rock. The more abundant rock seems to be a highly acid gneiss containing much quartz and orthoclase and minor amounts of disseminated fine graphite, biotite, and pyrite. The rock is indistinctly banded. The other kind of rock is a medium fine-grained gabbro in which there is disseminated flake graphite. Neither of these kinds of rock, judging from the specimens available, seems to have contained enough graphite to warrant the expenditure of money for a concentration mill.

The vein graphite was probably the material sought and the statements of the men living on the farm indicate that the veins were at least a few inches in thickness. Pieces of practically pure graphite

of that size are said to have been picked up near the mouth of the shaft many years after the mine was abandoned. These were pulverized and used for lubricating purposes.

Some specimens were obtained showing graphite veins cutting the acid gneiss. The veins seem to belong to two systems arranged approximately at right angles to each other and both cutting the bands of the gneiss at an angle. One of the veins is about ½-inch in thickness and is composed of practically pure graphite possessing a wavy foliated structure in which the individual leaves are roughly perpendicular to the walls of the fissure. Larger veins of this character, no doubt, constituted the ore mined and the separation of the graphite from the rock was done by hand.

GRAPHITE MINE NEAR LANGHORNE.

A graphite mine is said to have been operated at an early day near Glenlake, east of Langhorne, but no data could be obtained concerning it.

Graphite also occurs disseminated throughout the gneiss along Neshaminy Creek and northeast of Langhorne, but no attempts to mine it are known.

GRAPHITE IN FRANKLIN LIMESTONE.

A small area of coarsely crystalline limestone is exposed along the course of a small stream tributary to the Neshaminy Creek one mile southeast of Holland and three-fourths mile west of Neshaminy Creek. It has been extensively quarried in the Van Artsdalen quarry.

The limestone is mainly very pure and has been burned for lime but, in places, it is very impure due to segregations of various minerals, and besides it has been intruded by many dikes of gabbro. Graphite flakes are abundant throughout the limestone and a plan was at one time formulated to work the deposit for the graphite.

The quarry has long been a favorite locality for mineral collectors and about thirty different kinds of minerals have been reported from the quarry. Some of the most abundant, besides calcite and graphite are orthoclase, oligoclase, bytownite, scapolite, titanite, phlogopite, apatite, siderite, augite, and hornblende.

CHAPTER XIII.

USES AND PRICES.

USES OF PENNSYLVANIA GRAPHITE.

As stated elsewhere, all forms of graphite are not equally serviceable for all purposes and the product from any locality is limited to certain uses by its chemical and physical composition. To a certain extent, also, the use of Pennsylvania graphite is limited by conservatism and prejudice; the manufacturing trade is loath to believe that a new product is equally good in comparison with the material previously used with satisfactory results. The variation in the supply has likewise had its effect in preventing manufacturers from experimenting with the product. No company of any importance can afford to consider material from a new source unless assured that the supply will be ample for their uses and steady. Certainly the production of Pennsylvania graphite has been far too unsteady in the past to justify its use by the large consumers. Consequently, it is fair to assume that the Pennsylvania product possibly does not have as wide a variety of uses as it might have so far as its qualities are concerned.

Although no figures can be obtained to show the relative amounts of Pennsylvania graphite used for different purposes it is the opinion of persons interested that the largest amounts are consumed in the manufacture of crucibles and lubricants and the remainder goes into stove blacking and foundry facings.

Although certain crucible manufacturers claim that American flake graphite is entirely unsuitable for the manufacture of crucibles, others claim that it is eminently satisfactory and claim that the crucibles made of American flake are as desirable as those made of Ceylon graphite. Without considering the merits of the two claims it is interesting to know that more Pennsylvania graphite is used in the manufacture of crucibles than for any other single purpose.

Next in importance is the use of Pennsylvania graphite in the manufacture of lubricants. For such purposes a soft flake free from grit is demanded and much of the cleaned graphite of Chester county conforms to such requirements. Small amounts of mica that may be present are not especially objectionable for such uses.

The very fine graphite flake and graphite dust produced by the graphite mines of this State are consumed in the manufacture of stove polish and for foundry facings. For these purposes a less pure

product is demanded than for crucibles and lubricants and the fine particles that cannot be easily cleaned and which would otherwise be wasted can thus be utilized.

In addition to the above-mentioned uses of Pennsylvania graphite, there may be other minor uses where mixtures of materials from various sources are used. Most dealers in graphite obtain their materials from many different places and mixtures or blends are prepared dependent upon the requirements of the trade. Pennsylvania graphite in small amounts may enter into these, especially the dust and small flakes, but the manufacturers of articles named above certainly consume the greater portion of the production of this State.

PRICES OF PENNSYLVANIA GRAPHITE.

The price of graphite flake depends so much on the physical and chemical composition, as well as on the supply and demand, that it is difficult to determine the average prices for any year or period of years. The best flake of one company may be as high in carbon as the best flake of another company but the flake of one company may be more brittle or of smaller size so that it would be far less desirable and command a much lower price. The price of the various grades for the past two years range about as follows:

No. 1 Crucible flake, $6\frac{1}{4}$ to $6\frac{1}{2}$ cents per pound.

No. 2 Crucible flake or Super X $5\frac{1}{2}$ to $6\frac{1}{2}$ cents per pound.

No. 90 flake, $4\frac{1}{2}$ to $5\frac{1}{2}$ cents per pound.

No. 119 dust 2 cents per pound.

No. 2-90 dust $12 to $15 per short ton.

During 1911 the prices for all grades were somewhat lower than in 1910. The highest prices ever obtained for Pennsylvania graphite, at least for many years, were reached during 1898 when the values were almost double the average price due to the large amount required for the manufacture of graphite crucibles to be used in making cast steel for projectiles during the Spanish-American war.

It is well to remember that the prices of the various grades of flake and dust do not necessarily prove that the company is working at a profit or not. One must know the relative amounts of high priced and low priced material and the per cent. of extraction of graphite from the ore as well as the cost of production.

CHAPTER XIV.

PRODUCTION OF PENNSYLVANIA GRAPHITE.

The statistics of the production of graphite in Pennsylvania are taken mainly from the Mineral Resources of the United States of the United States Geological Survey. The data were obtained from

the individual producers on the express assurance that they would not be published in such form that competitors might learn their individual output. Consequently the policy has been adopted of not giving the production of individual states unless there are three or more operators producing. In many years there have been less than three companies reporting production in Pennsylvania, hence the State's production for many years cannot be given. Those years in which there is known to have been some production but the amount not published are marked by a *.

Year.	Amount in tons.	Value.
1886,	*	
1887,		
1888,		
1889,	*	
1890,	500	$20,500
1891,		
1892,	50	?
1893,		
1894,		
1895,	*	
1896,	*	
1897,	*	
1898,	*	
1899,	*	
1900,	*	
1901,	*	
1902,	*	
1903,	*	
1904,	*	
1905,	222	?
1906,	*	
1907,	*	
1908,	178	$16,740
1909,	1,049	116,466
1910,	696	82,194
1911,	745	80,300

WORLD'S PRODUCTION OF GRAPHITE.

For purpose of comparison with the foregoing table the production of the principal graphite-producing countries of the world are given for the years 1901 to 1910 inclusive.

	1901.		1902.		1903.		1904.		1905.	
	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.
Austria,	29,992	$1,918,500	29,527	$368,186	32,616	$382,148	31,548	$386,082	37,937	$274,154
Canada,	2,210	38,780	1,095	28,300	728	23,745	452	11,760	541	17,033
Ceylon,	22,707	3,203,215	25,593	3,505,455	26,998	1,952,529	29,187	2,110,873	34,319	2,307,012
France,	----	----	150	1,140	139	689	17	130	110	1,351
Germany,	4,435	58,000	5,023	41,755	4,099	35,411	4,171	40,122	5,424	49,742
India,	2,530	----	4,648	----	3,801	82,474	3,647	81,288	2,603	82,085
Italy,	10,313	59,211	9,210	----	8,730	28,855	10,764	44,542	11,654	52,104
Japan,	88	8,930	97	9,876	126	10,950	238	18,026	230	18,201
Mexico,	1,473	7,385	580	3,176	1,548	41,635	1,069	47,436	1,069	42,916
Norway,	----	----	----	----	----	----	----	----	----	----
Queensland,	----	----	----	----	----	----	----	----	36	1,324
Sweden,	56	1,900	63	1,900	28	988	61	1,755	44	1,276
United States,	2,533	167,714	6,085	182,108	18,860	225,554	19,768	321,372	24,971	318,211

WORLD'S PRODUCTION OF GRAPHITE.—Continued.

	1906.		1907.		1908.		1909.		1910.	
	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.
Austria,	42,016	$293,615	53,013	$387,930	48,970	$349,118	45,194	$320,380		
Canada,	446	18,780	579	16,000	251	5,565	864	47,800		
Ceylon,	40,320	3,406,550	36,406	2,889,596	28,916	2,593,160	28,660	2,587,531		
France,	276	2,433	138	1,206						
Germany,	4,470	47,122	4,409	45,671	5,340	60,264	7,716	63,111		
India,	2,912	48,709	2,725	35,949	3,218	69,814	3,527	79,536		
Italy,	11,910	61,162	12,125	61,374	14,235	71,758	12,787	70,445		
Japan,	155	12,191	115	5,222	195	8,592	220	8,492		
Mexico,	4,315	77,110	3,530	54,339	1,742	28,426				
Norway,	2,101	5,884	1,543	14,974	1,192	13,005				
Queensland,	34	973	34	965	22	292	22	290		
Sweden,	41	1,197	36	946	73	2,046	73	2,046		
United States,	19,797	340,239	29,277	296,970	2,587	208,090	8,243	345,509	38,740	$377,176

CHAPTER XV.

OUTLOOK FOR THE GRAPHITE INDUSTRY IN PENNSYLVANIA.

The history of graphite mining in Pennsylvania has been a precarious one and it can be said without exaggeration that it has cost several dollars to produce every dollar's worth of graphite that the State has yielded. It should be remembered, however, that Pennsylvania graphite does not stand alone in this respect. A recognized authority has recently maintained that on an average it requires an expenditure of two dollars to produce one dollar of gold and a prominent operator in our greatest zinc producing region of the United States has recently stated that, in his opinion, it was outside capital that was responsible for the continuation of mining in that district. The insane fascination of mines and mining stock that will cause otherwise cautious and conservative persons to invest in mines on the most exaggerated prospectuses must be considered. When we are dealing with a substance that is imported to the value of many thousands of dollars annually from a country as remote as Ceylon, as is graphite, we have a further reason why graphite mines have been considered good promoting properties.

The curse of the graphite industry of the past has been the fact that the owners of the mines have either been desirous of securing returns from their investment through the sale of stock or have failed to appreciate the difficulties attending the concentration of the graphite and have expended money in an extravagant and entirely unjustifiable manner. It is idle to expect that the immense paper profits promised by the promoter could ever be realized and it is also readily apparent even to the novice that no mining company could ever pay legitimate dividends when mills are seen to contain thousands of dollars worth of practically useless machinery as has been true in the case of several companies that have operated in the graphite districts of Berks and Chester counties.

In graphite mining, as in other forms of mining, the failure of a company to yield a fair income on the capital invested almost invariably results in the shutting down of the mine, in litigation, and finally in reorganization. Many of the graphite mines of Pennsylvania have passed through these successive stages, not once only but several times. Further, with each reorganization, the mill equipment has been radically changed, new men have been placed in charge, and the same order of events has taken place. In brief, the instability of the operating companies has prevented a fair trial of the district.

The greatest difficulty in all the graphite mines of the State has been the problem of concentration. It is generally admitted that the cleaning of the graphite flake is, at present, in the experimental stage. That this is so, is apparent when no two mills can be found in which the same kinds of machinery and same processes are in use, as is described in a previous chapter. Admitting this, it is reasonable to expect that no company that fails to appreciate this difficulty can succeed.

Many of the graphite mines have been over-capitalized to such an extent that it has been impossible for them to ever yield a fair return on the investment. In the case of one company, it is stated that more than $2,000,000 was realized through the sale of stock, a sum entirely out of proportion to the possible profits that could be made from the mines operated.

Notwithstanding the deplorable features that in the past have prevented the profitable production of graphite by many of the companies operating in Pennsylvania, there is no need of considering the graphite industry pessimistically. There is no scarcity of good graphite rock that will carry from 2% to 4% of good flake graphite and that is reasonably free from objectionable minerals such as mica, while in some cases the percentage runs as high as 7%. It is also mined easily as there is little or no surface barren material to be removed, and many deposits can be worked as open mines. The problem of crushing the ore is also less serious than in some other districts as the graphite rock is so greatly decomposed that in some of the mines the rotten rock is encountered at depths exceeding 100 feet. Many of the mines have operated only in the decomposed rock. Others, however, have encountered fresh graphite rock in which the feldspar had not undergone much kaolinization at lesser depth and the problem of crushing is a more expensive one. But even in the case of the fresh rock, crushing is not difficult and is effected with far greater ease than with the graphite ores of the Dixon Crucible Company at Graphite, New York, where the highly siliceous ores have been so extensively and profitably worked for many years. The supply of water for concentration of the ore is readily obtained and, in several places, the mine water is sufficient. In other places a supply has been obtained from wells or has been pumped from nearby creeks. In other words, the natural difficulties in the way of profitable production are not of such a character as to discourage operation.

What is needed far more than anything else is conservatism and stability. The cost of equipment of a good mill should not exceed $50,000 to $100,000 depending on the size and the kind of machinery adopted. Further it should not be expected that the mill should at once be able to reach its maximum output of clean graphite for it has been the experience of all graphite mill men that each kind of ore

presents certain peculiar features and these must be determined. Experienced men are needed in the concentration of graphite far more than in the concentration of other ores, particularly the metallic ores, because of the slight differences in specific gravity between the graphite and tho gangue minerals. It also seems to be easier to recover the heavier than the light particles while in the graphite concentration the mineral sought is the one with the lower specific gravity. No mill should be pronounced a failure until it has had a fair trial. Yet in the past, mills have been condemned and re-equipped with new and expensive machinery because the product was not sufficiently well cleaned at the start or the greater part of the graphite recovered.

Economy must also be practiced in graphite mining as in other industries if the balance is expected to appear on the right side of the sheet. At best the profits are not so large as to justify the excavagance shown by some companies in the past that invited failure by the unnecessarily large force of men employed and by the purchase of useless appliances. If experimentation is to be done it is better to do it on a small scale first and await the results before making large investments that may yield no returns.

Finally the market for graphite should be carefully considered. At one time it was thought that all forms of graphite were equally serviceable for all purposes for which graphite could be used. At the present time it must be recognized that certain graphite manufacturers prefer Ceylon graphite for crucibles and amorphous graphite from Mexico or Austria for lead pencils. The field for Pennsylvania flake graphite is thus being restricted. Artificial graphite is also becoming a more important competitor every year in the manufacture of lubricants, paints, and for electrical purposes. On the other hand, the demand for graphite is constantly increasing as its value for new purposes is shown. So far thero has never been an over-supply of flake graphite but it should be remembered that the present demand would not justify a great and sudden increase in the output. It is fairly certain, however, that a normal and gradual increase might be made for many years without producing any change in the market price.

A discussion of this question by Prof. F. D. Chester who has had several years experience in graphite mining and milling in this State was published* a few years ago and is here quoted.

"Various efforts have been made during the last 10 or 15 years to organize and maintain the flake-graphite industry in the United States, but merely as an industry for the production of graphite in its crude form independent of the manufacture of graphite pro-

*Eng. and Min. Jour., Vol. 88, pp. 785-786, 1909.

ducts it has rarely been a success. Today there are more abandoned mines and costly plants than those in operation, and the question might be asked, why does this condition of things exist?

"Every enterprise which has ever started has been founded on hope, and large sums of money have been ventured by promoters and organizers who have had very little true idea of commercial facts as applied to graphite, and still less of the technical side of its milling operations. Thus, where mistakes have been made it has frequently been at the start, due to errors of judgment, which in turn have been the result of inexperience. Experience is costly, and mistakes must be made before it is gained, and where this cost has to be met by a host of stockholders, the latter are liable to lose confidence too soon, and often on the very eve of successs.

MILLING OF GRAPHITE ORES NOT REDUCED TO A SCIENCE.

"It should be understood that the technology of graphite is as yet in a formative stage, and that there is no established system or scientific basis, such as applies to most of the mining industries, and for this reason operators are groping more or less in the dark. The industry is as yet too unimportant to attract the attention of the best experts in ore dressing, and it has been largely in the hands of local mechanics, who lack the proper scientific training and broad knowledge, so necessary to the working out of a difficult problem. The difficulties are still further increased by the variable characteristics of the ores of different mines, making each problem in a measure a local one, so that whhile some mines which have had longer experience than others may have worked out a satisfactory system of milling for their own type of ore, this experience may not be applicable to someone else. But what has been most lacking has been the absence of fundamental principles to form a basis of guidance, resulting in too much haphazard empiricism and too many costly undertakings which were fundamentally wrong.

COMMERCIAL FEATURES OF INDUSTRY.

"Thus while success is in a large measure dependent on the direction given the technical side of the industry it is not altogether that, and the business side is equally important. It is largely a question of the difference between the cost of production and the market value of the product, and this balance is determined by a variety of conditions. If flake graphite were a staple product like copper, lead or silver, produced by established methods and salable at all times in the open market at the fixed market price, the sales end would be simplified, but it is a manufactured product, of variable quality and market value, and is subject to laws of competition. which are also unusually severe because American flake has as yet to win a secure place in the market. Even if graphite could be con-

sidered as a raw material, and could be sold on some uniform basis of price, as so much for each unit of carbon, the marketing of the product would be simplified, and it would be fairer both to the producer and the buyer. But no such system of determining values has ever had general application.

"In general the cost of producing flake graphite is so high and the price at which it is sold is so low, that even under the most economic conditions the margin of profit is small. In many cases the cost of production has considerably exceeded the returns, and inevitable failure has eventually followed. Many ores are of too low a grade, or the expense of mining and milling them too high, to be profitable Other ores are of such a character that the percentage of extraction under existing methods is unsatisfactory. These are weak points at the very start, which an experienced man should be able to see, before any money is spend on what is sure to be an unprofitable venture.

GRADE OF THE ORE.

"Just what grade of ore can be handled with a profit depends on the expense of mining, cost of reduction, and its milling qualities. There are instances where ores yielding as low as 2 per cent. of graphite carbon can be handled at a profit, but probably this approaches very close to the limit. By this is meant an actual yield in marketable graphite of 40 lbs. of actual carbon to each ton of ore handled; it does not refer to the actual percentage of crude graphite in the ore. Graphite investors are commonly misled by assay reports. These assays are frequently made from selected samples, and even when an honest effort is made to obtain an average sample it is invariably a flattering one, and rarely represents the ore handled over a long period. For this reason there is only one method of getting at results of practical value, and that is to go by actual mill tests of a definite quantity of ore, determining the weight and actual amount of carbon in the resulting concentrates."

The above statements are not made with the intention of discouraging investment in the graphite industry of Pennsylvania but in stead it is the purpose of the writer to point out the reasons why there have been so many disastrous failures in the past. Graphite mining in Pennsylvania has received much condemnation which it does not deserve and it is to be hoped that the industry may be kept completely out of the hands of stock promoters and retained on a stable basis. Certain operators in this State and also in New York have shown that there is money to be made in graphite mining and this should encourage the graphite operators. Moderate capitalization, conservative expenditures, stable financial management and experienced superintendence should yield satisfactory returns in the graphite industry in Pennsylvania in the future as in the past.

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1825

VANUXEM, LARDNER.

Experiments on Anthracite, Plumbago, &c.

Jour. Acad. Nat. Sci., Phila., 1st Ser., Vol. V. Pt. I, pp. 17-27, 1825.

Gives an analysis of graphite "from near Bustleton."

This is the mine near the present station of Trevose.

The analysis is as follow:

Carbon,		94.40
Water,		0.60
Residue by incineration, Colour light brick red,	5.0 consisting of	
Silex,		2.60
Oxides of iron and manganse,		1.40
Loss,		1.00
		100.00

1828.

CARPENTER, GEORGE W.

On the Mineralogy of Chester County, with an account of some of the Minerals of the Delaware, Maryland ,and other localities.

Amer. Jour. Sci., Vol. XIV, pp. 1-14, 1828.

Plumbago is reported from East Bradford and Charleston townships, Chester Cuonty, from Bucks County near present station of Trevose, and from Robinson's Hill on the Schuylkill River, 5 miles from Philadelphia.

1829.

MORTON, S. G.

Analysis of Tabular Spar from Bucks County, Pennsylvania: with a notice of various minerals found at same locality.

Jour. Acad. Nat. Sci., Phila., 1st Ser. Vol. VI, Pt. I, pp. 46-49, 1829.

Description of minerals found on farm of Jacob Van Arsdalen. "Graphite, massive, and in delicate hexagonal tables, disseminated in all the other minerals. It may be remarked that Mansell's Black Lead mine is only a mile and half distant, where this mineral is found in great abundance in Syenite."

1839.

TOWNSEND, WILLIAM P.

A Report on the Minerals of Chester County, that are used in the arts, read before the West Chester Lyceum, March 30, 1839. 10 pp. West Chester, Pa.

In discussing the various minerals of the county the author says: "In West Nantmeal, considerable quantities of Black Lead, called Graphite, are found not compact disseminated through blue quarts." (p. 8).

1840.

ROGERS, HENRY D.

Fourth Annual Report on the Geological Survey of the State of Pennsylvania.

252 pp. Harrisburg, 1840.

On page 14 the following statement appears: "Rather more than a mile south of the Buck tavern, on the banks of the north branch of the Paquasin Creek, there is a locality where Plumbago, or black lead, was formerly worked, but the place is abandoned, and the pit filled up." Several localities where graphite flakes occur in coarse crystalline limestones are also mentioned. (pp. 27, 28, 32).

1841.

Fifth Annual Report on the Geological Survey of Pennsylvania.

179 pp. Harrisburg, 1841.

Crystalline tremolite containing graphite is said to occur at Chestnut Hill, Easton. (p. 19).

1858.

The Geology of Pennsylvania. Vol. I, 586 pp. Vol. II, 1045 pp. Maps and plates, Philadelphia, 1858.

Short descriptions are given of old graphite mines near Trevose, Bucks County (Vol. I, p. 81) and a short distance southwest of Pughtown, Chester County (Vol. II, p. 709). Other occurrences of the mineral graphite in the State are mentioned in several places. (Vol. I, pp. 87, 89, 90, 95, 224-225, 231, 232; Vol. II, pp. 710, 712).

1875.

GENTH, F. A.

Preliminary Report on the Mineralogy of Pennsylvania.

Sec. Geol. Survey of Pa., Report B. 238 pp. Harirsburg, 1875.

Many localities where graphite has been found are mentioned. These occur in the following counties: Bucks, Northampton, Lehigh, Berks, Philadelphia, and Chester.

1881.

FRAZER, PERSIFOR.

Relations of the Graphitic Deposits of Chester County, Pa., to the Geology of the Rocks Containing Them.

Trans. Amer. Inst. Min. Eng., Vol. IX, pp. 730—733, 1881.

Describes the operations of the Pennsylvania Graphite Co. at Windsor, (Byers) during the summer of 1880. The extent and characteristics of the ore body and the methods of mining and milling are described. The graphite is believed to indicate the Laurentian or Lower Huronian age of the rocks.

HALL, CHARLES E.

The Geology of Philadelphia County and of the southern parts of Montgomery and Bucks.

Sec. Geol. Survey of Pa., Report C 6, 145 pp. Harrisburg, 1881.

"Southeast of Feasterville and north of Brownsville, on A. Johnson's farm, plumbago has been mined. It occurs disseminated through the feldspathic and quartzose rock. Some pockets of considerable size have been found but the quantity is not sufficient to pay for working, and the mine has long since been abandoned." (p. 59).

On p. 105 is given an analysis and description of graphite gneiss from the "west side of Neshaminy Creek on the farm of Phineas Paxon," and on pages 115-116 an analysis of graphite gneiss from "Johnson's Graphite Mine, about one mile east of Feasterville." The mine mentioned is the long abandoned one near the station of Trevose, Bucks County. Graphite is also said to be present in pyroxene syenite from Van Artsdalen's quarry, (p. 104) and mixed with a chloritic mineral resembling delessite in same place. (p. 105).

1883.

D'INVILLIERS, E. V.

The Geology of the South Mountain Belt of Berks County.

Sec. Geol. Survey of Pa., Report D 3, Vol. II, Pt. I, 441 pp., Harrisburg, 1883.

Reference is made to the abandoned graphite mines west of Boyertown (pp. 94-95) and near Longswamp (p. 105) and to specimens of graphite bearing rock at the former locality (p. 387). Other localities where graphite was observed are mentioned. (p. 397).

FRAZER, PERSIFOR.

The Geology of Chester County.

Sec. Geol. Survey of Pa., Report C 4, 394 pp., Harrisburg, 1883.

Contains a description of the mine of the Pennsylvania Graphite Company at Windsor (Byers) (pp. 251-253), quotes Prof. Rogers' description of the old graphite mine near Pughtown (pp. 221-222), and refers briefly to the prospecting operations of the Chester Springs Plumbago Mining and Manufacturing Company in West Pikeland township (p. 232). He also mentions the presence of graphite in coarse granular limestones in Pickering Valley, (pp. 82, 83, 125) and West Nantmeal (p. 168) and associated with the iron ores of the county (pp. 167, 172, 174).

1898.

HOPKINS, T. C.

Descriptions of Graphite Properties near Chester Springs, Chester County, Pa.

Mineral Industry, Vol. VII, p. 383, 1898.

Brief description of the mines of the Philadelphia Graphite Company at Chester Springs and Pettinos Bros. at Byers.

1899.

HOPKINS, T. C.

Description of the Occurrence of Graphite in Berks County, Pa.

Mineral Industry, Vol. VIII, p. 350, 1899.

1901.

HOPKINS, T. C.

Graphite and Garnet.

Mines and Minerals, Vol. XXI, p. 352, 1901.

Contains brief description of the operating mines located at Chester Springs, Byers, Boyertown and Mertztown.

DOWNS, W. F.

Graphite—Pennsylvania.

Mineral Industry for 1900, Vol. IX, pp. 378-379, 1901.

Short description of the occurrence of graphite in the Pickering Valley with a list of the operating companies during 1900.

1902.

ANONYMOUS.

Graphite—Pennsylvania.

Mineral Industry for 1901, Vol. X, 1902.

Account of the graphite industry in Pennsylvania during 1901. Descriptions of the depostis near Chester Springs and Mertztown.

1903.

STRUTHERS, JOSEPH.

Graphite—Pennsylvania.

Mineral Industry for 1902, Vol. XI, pp. 347-348, 1903.

Description of method of treatment of graphite concentrates by the Federal Graphite Company of Chester Springs.

1906.

JUDD, EDWARD K.

Graphite—Pennsylvania.

Mineral Industry for 1905, Vol. XIV, p. 311, 1906.

Short account of the activities of the Pennsylvania Graphite companies during 1905 with an estimate of production.

LAW, E. STANLEY.

Notes on a useful mineral (graphite).

The Mineral Collector, Vol. 12, pp. 169-173, 180-184.

A general account of the properties, occurrence, and uses of natural graphite with a short description of the artificial product. The Pickering Valley deposits are briefly described and, in particular, one property near Chester Springs, presumably that of the Federal Graphite Company.

1909.

CHESTER, FREDERICK D.

The Flake Graphite Industry in the United States.

Eng. and Min. Jour., Vol. 88, pp. 785-786, 1909.

A discussion of the problems that confront the graphite miners. The writer claims that the cleaning of the graphite flake has not been reduced to a science and that under the most favorable economic conditions the margin of profit is small. He considers that no ores yielding less than 2 per cent. marketable graphite can probably be worked at a profit.

Concentration of Flake Graphite.

Eng. and Min. Jour., Vol. 88, pp. 824-825, 1909.

A discussion of the commercial considerations in the concentration and refining of graphite. A formula is deduced showing the relative proportions of flake and dust that should be obtained in the refinlng of the various grades of graphite concentrates.

1910.

ANONYMOUS.

Graphite.

Mines and Minerals, Vol. XXX, pp. 394-395, 1910.

A description of the properties, occurrence and distribution of graphite. The Ceylon operations are described rather fully, and also the method of concentrating the flake graphite at the plant of the Chester Graphite Company at Chester Springs, Pa. A flow sheet of the process accompanies the description.

1911.

BASTIN, EDSON S.

Graphite—Pennsylvania: Condition of Industry.

Mineral Resources of U. S. for 1909, Pt. II, pp. 824-830. U. S. Geol. Survey, 1911.

The working graphite mines of the Pickering Valley region were visited during 1909 and are briefly described in this article. Also descriptions of the abandoned Berks County mines are quoted from an earlier article by Hopkins.

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Graphite in the Haystack Hills, Laramie County, Wyo.

Bull. U. S. Geol. Survey, No. 315, pp. 426-428, 1906.

Brief description of amorphous graphite prospects of Laramie County, Wyoming.

BASTIN, EDSON S.

Origin of Certain Adirondack Graphite Deposits. Econ. Geol., Vol. V, pp. 134-157.

The writer believes that the graphite deposits of New York fall into two groups; (a) those which originated through dynamic (regional) metamorphism alone, and (b) those which have been affected successively by dynamic and by igneous (contact) metamorphism. Descriptions of the two classes are given.

BAYLEY, W. S. and STEWART, C. A.

Note on the Occurrence of Graphite Schist in Tuxedo Park, N. Y. Econ. Geol., Vol. III, pp. 535-538, 1908.

A description of the methods of occurrence of graphite in the highlands of New Jersey and southeastern New York with a discussion of its probable origin which is believed to be sedimentary.

BILHARZ, O.

Das Vorkommen von Graphit in Bohmen, insbesondere am Ostrande des sudlichen Bohmerwaldes.

Zeit. Prakt. Geol., Vol. XII, pp. 324-326, 1904. (Abstract) Trans. Inst. Min. Eng. Vol. 27, pp, pp. 613-614.

Descriptions of the graphite regions of Bohemia, the Saaz Mountains district close to the Moravian frontier and the Bohemian Forest district which is geologically and genetically connected with the Bavarian graphite deposits about Passau.

BREWER, WILLIAM M.

Occurrences of Graphite in the South.

U. S. Geol. Survey, 17th An. Rep., Pt. III, pp. 1008-1010, 1896.

Brief descriptions of the distribution of the graphite-bearing rocks of Alabama and Georgia. Principal mining is reported to be carried on in Bartow County, Georgia, and Clay County, Alabama.

BRUMMELL, H. P. H.

Canadian Graphite.

Jour. Can. Min. Inst., Vol. X, pp. 85-104, 1907. Can. Min. Jour., Vol. XXVIII, pp. 163-171, 1907. Abst. Min. World, Vol. XXVI, p. 627, 1907.

Descriptions of the graphite deposits and the graphite industry of Canada.

Regarding Lead Pencils.

Can. Min. Jour., Vol. XXVIII, p. 173, 1908.

History of the manufacture of lead pencils.

Graphite Concentration.

Jour. Can. Min. Inst., Vol. XII, p. 205, 1909. Can. Min. Jour., Vol. XXX, pp. 267-272, 1909

Descriptions of the various machines used in the concentration of graphite and the processes employed by the Canadian graphite companies.

CIRKEL, FRITZ.

Graphite; Its Properties, Occurrence, Refining and Uses.

Dept. of Mines, Ottawa, Canada, 307 pp. 1907.

(Rev.) Econ. Geol., Vol. IV, pp. 661-666, 1909.

(Rev.) Eng. and Min. Jour., Vol. LXXXV, pp. 360-361, 1908.

The most complete discussion of graphite thus far published, it covers the whole field of economic developments of graphite deposits.

CUSHING, H. P.

Geology of the Northern Adirondack Region.

New York State Museum, Bull. No. 95, 1905.

Describes the graphite of the Grenville series of pre-Cambrian rocks.

DOWNS, W. F.

The Occurrence, Treatment and Application of Graphite.

Iron Age, Vol. LXV, Apr. 19, p. 8, May 3, pp. 3-6. May 10, pp. 9-11, May 24, p. 5, June 14, 26e-26f. New York, 1900.

A short account of the properties and distribution of graphite. An excellent discussion of graphite crucibles.

GALE, HOYT S.

Supposed Deposits of Graphite near Brigham, Utah.

U. S. Geol. Survey, Bull. No. 225, pp. 639-640, 1910.

A description of some carbonaceous schists that were supposed to be graphite but on careful examination were proved to contain only amorphous carbon.

HAENIG, A.

The Application of Graphite to the Production of Crucibles for Melting Metals. (Abstract translation from Der Graphit.) Brass World, Vol. VII, pp. 307-312, 351-352, 1911.

A discussion of the mixtures used in the manufacture of crucibles.

HAYES, C. W. and PHALEN, W. C.

Graphite Deposits near Cartersville, Ga.

Bull. U. S. Geol. Survey, No. 340, pp. 463-465, 1907.

Consists of a short description of graphitic talcose slates of Bartow county. The slates extend for many miles and are being worked by two companies. The rock was originally a carbonaceous clay shale. The graphite is amorphous and is present in the rocks in varying amounts from 4 per cent. to 9 per cent.

HESS, FRANK L.

Graphite Mining near La Colorado, Sonora, Mexico.

Eng. Mag., Vol. XXXVIII, pp. 36-48, 1909.

Abst., Min. Resources of U. S. for 1908, Vol. 2, p. 734, 1909.

Description of the important amorphous graphite deposits of Sonora, Mexico, which have been formed from a coal bed by contact metamorphism.

HITCHCOCK, EDWARD.

Report on the Geology of Massachusetts, Pt. I. Economic Geology. 70 pp. map. Amherst, 1832.

Reprinted with slight corrections in 1833.

Contains a description of a graphite mine in Sturbridge which had recently been re-opened after being abandoned for many years.

Final Report on the Geology of Massachusetts. 831 pp. Illus. Northampton, 1841.

Describes a graphite mine in Sturbridge, Mass., and mentions other localities in the State where graphite occurs.

HYDE, F. S.

Some characteristics of Natural Graphite.

Eng. and Min. Jour., Vol. LXXXV, pp. 255-256, 1908.

An account of the physical characteristics of graphite and its behavior when subjected to various chemical tests.

IHNE, F. W.

Graphite in the South.

Manufacturers' Record, Vol. LIV, pp. 134-138, 1909.

Contains descriptions of the graphite deposits of Georgia, North Carolina and Alabama.

Graphite in the United States.

Mining Science, Vol. LX, pp. 297-298, 316-318, 343-346, 1909.

The known graphite deposits of the United States are briefly discussed.

IMPERIAL INSTITUTE.
Graphite and its Uses.
Bull. Imperial Inst., Vol. IV, pp. 353-360, 1906.
Vol. V, pp. 70-85, 1907.
Abst., Can. Min. Jour., Vol. XXVIII, pp. 171-173, 1907.
Describes the physical and chemical characters of graphite, its mode of occurrence, uses, concentration and distribution throughout the world.
Pennsylvania deposits are not mentioned.

JAMISON, C. E.
Mineral Resources of Wyoming.
Bull. No. 1, Series B, 102 pp. Cheyenne, 1911.
Contains a paragraph describing briefly the graphite deposits of the State.

JAPAN, MINING IN, PAST AND PRESENT.
Bureau of Mines, pp. 133-135, 1909.
Brief description of the Japanese graphite deposits. Occurs in form of crystalline scales in Archean gneiss, as amorphous masses in Paleozoic slate and Mesozoic shale, and in veins.

KEMP, J. F. and NEWLAND, D. H.
Preliminary report on the Geology of Washington, Warren, and Parts of Essex and Hamilton Counties, N. Y.
Fifty-first An. Rept. N. Y. State Museum, Vol. 2, pp. 537-540, 1897.
Describes the graphite deposits at Hague, N. Y.

KEMP, J. F.
Graphite in the Eastern Adirondacks, N. Y.
Bull. U. S. Geol. Survey, No. 225, pp. 512-514, 1903.
Describes the method of occurrence and distribution of graphite in the Eastern Adirondack region.

KEMP, JAMES F. and RUEDEMANN, RUDOLF.
Geology of the Elizabethtown and Port Henry Quadrangles.
New York State Museum, Bull. No. 138, 173 pp. 1910.
Contains descriptions of the occurrence of graphite in the Grenville series of crystaline rocks.

KEITH, ARTHUR.
Mount Mitchel (N. C.—Tenn.) Folio (No. 124).
U. S. Geol. Survey, 1905.
Contains description of the graphite-bearing rocks near Graphiteville, N. C.

KNIGHT, W. C.
Geology of the Wyoming Experiment Farms, and Notes on the Mineral Resources of the State.
Wyoming Exper. Sta. Bull. No. 14, pp. 103-212, Laramie, 1893.
Contains a short article on "Plumbago," in which descriptions are given of a few localities where it has been found.

KUMMEL, HENRY B.
Notes on the Mineral Industry, with Mineral Statistics.
An. Rep. State Geol. of New Jersey for 1907, pp. 169-181. Trenton, 1908.
On page 177 the writer describes the operations at the High Bridge graphite locality.

LEE, WILLIS T.
Graphite Deposits near Raton, New Mexico.
Min. Resources for 1908; Vol. 2, U. S. Geol. Survey, p. 733, 1909.
Short description of the graphite deposits near Raton, N. Mex. formed by the intrusion of diabase into a coal bed.

MERRILL, GEORGE P.
Graphite.
The Non-Metalic Minerals, pp. 4-12, New York, 1905.
A general account of the properties, occurrences, sources, uses, preparation, statistics, and a short bibliography. Brief mention of Pennsylvania localities (p. 9).

MILLS, FRANK S.
The Economic Geology of Northern New York.
Eng. and Min. Jour., Vol. LXXXV, p. 397, 1908.
Describes a graphite deposit in Macomb township, St. Lawrence county.

MILLS, JAMES COOKE.
The Graphite Mines of Santa Maria.
Mines and Minerals, Vol. XXIX, pp. 98-100, 1908.
Describes the methods of cleaning and marketing the graphite. Also short descriptions of other graphite localities in various parts of the world.

MINERAL INDUSTRY.
Vols. I to XIX, 1892 to 1910. An annual volume. Early volumes published by the Engineering and Mining Journal; later ones by McGraw-Hill Publishing Co.
Each volume contains a summary account of the graphite industry of the year. Particular attention is given to the industry in the United States and Canada but certain volumes contain descriptions of foreign localities.

MINERAL RESOURCES OF THE UNITED STATES.
U. S. Geological Survey. Annual volumes, 1881 to 1910.
Each volume contains a brief report on the graphite industry of the United States for the particular year. The earlier volumes contain little information other than statements of production. The later ones include brief descriptions of the graphite deposits of the country with mention of foreign localities.

MOFFIT, FRED H.
The Nome Region.
Bull, U. S. Geol. Survey, No. 314, pp. 139-140, 1907.
Graphitic schists and graphite-bearing pegmatites exposed in the upper valleys of Grand Central River and Windy Creek are described. Is not believed that the graphite could be worked with profit at the present time.

NASON, FRANK L.

Geological Studies of the Archaean Rocks.

An. Rep. State Geol. of New Jersey for 1889, pp. 12-65, Camden, 1889.

On pages 27-29 and 64-65, especially, the author discusses the distribution of graphite throughout the State of New Jersey and its relation to the iron ore belts.

NEWLAND, D. H.

The Mining and Quarry Industry of New York State.

New York State Museum Bulls. No. 93 for 1904, No. 102 for 1905, No. 112 for 1906, No. 120 for 1907, No. 132 for 1908, No. 142 for 1909.

These bulletins contain much information concerning the New York graphite deposits.

NICHOLAS, FRANCIS C.

A Novel Graphite Washing Plant.

Min. World, Vol. XXVIII, p. 18, 1908.

Describes the milling process of the Empire Graphite Company, operating near Saratoga, N. Y. The ore is first crushed by rock breakers and rolls and then mixed with water and thoroughly stirred in steel-lined cement buddles for about two hours. It passes next to a second set of buddles, thence to wet screens, dryer, and silk screens.

OGILVIE, IDA H.

Geology of the Paradox Lake Quadrangle, N. Y.

Bull, N. Y. State Museum No. 96, pp. 503-505, 1904.

Describes graphite deposits occurring at the town of Graphite and at Rock Pond. The origin of the graphite is attributed to organic matter as shown in quotation. "It therefore appears as though the graphite deposits were a result of impregnation along a line of weakness by some products, possibly volatile hydrocarbons, originating from the distillation of originally fossiliferous sediments."

PRATT, J. H.

The Mining Industry of North Carolina.

North Carolina Geological Survey Economic Papers, Nos. 4, 6, 7, 8, 9, 11, 14 and 23, 1900 to 1910.

These papers contain descriptions of the graphite deposits of North Carolina, especially Nos. 6 and 9.

RIES, HEINRICH.

Economic Geology, 589 pp. New York, 1910.

Graphite, pp. 241-246.

General account of properties, occurrences, distribution, uses, statistics, and short list of references. Brief mention of Chester county localities (p. 243).

ROWE, JESSE PERRY.

Graphite Deposits in Montana.

Min. World, Vol: XXVIII, p. 839, 1908.

Describes vein graphite occurring in a quartzite schist of pre-Cambrian age, 11 miles southeast of Dillon.

Some Economic Geology of Montana.
Univ. of Mont. Bull. No. 50, Geol. Ser. No. 3, 70 pp. Missoula, 1908.
Brief description of a graphite prospect 11 miles southeast of Dillon.

SADLER, S. S.
Determining Ash in Graphite.
Australian Mining Standard, Dec. 11, 1907.
Description of an analytical method.

SMITH, GEORGE OTIS.
Graphite in Maine.
Bull. No. 285, U. S. Geol. Survey, pp. 480-483, 1905.
Describes graphite deposits near Madrid, Franklin county, and Yarmouth, Cumberland county.

Graphite.
Min. Resources U. S. for 1905, U. S. Geol. Survey, pp. 1265-1269, 1906.
Concise statement of occurrence, uses, and production of graphite.

SMITH, PHILIP S.
Investigation of the Mineral Deposits of Seward Peninsula.
Bull. U. S. Geol. Survey, No. 345, p. 250, 1908.
A brief description of a graphite deposit on the north side of the Kigluaik Mountains, not far from Imuruk Basin. The graphite is said to be remarkably pure.

Recent Developments in Southern Sewārd Peninsula.
Bull. U. S. Geol. Survey No. 379, pp. 300-301, 1909.
Graphite is said to have a wide-spread distribution in the Kigluaik Mountains. A few tons have been marketed. "It has not yet been proved that it can be separated from the accompanying grit and transported economically."

STONIER, GEORGE A.
Graphite Mining in Ceylon and India.
Trans. Inst. Min. Engineers, Vol. 27, pp. 536-545, 1904.
An excellent description of the graphite mines of Ceylon and Southern India.

STUTZER, O.
Die Wichtigsten Lagerstatten der "Nicht-Erze."
Erster Teil, pp. 1-88, 15 figs., Berlin, 1911.
Review by E. S. Bastin, Econ. Geol., Vol. VI, pp. 512-513, 1911.
Contains a general account of graphite and graphtie deposits. Brief descriptions of the graphite deposits of the world are included and a concluding discussion on the origin of graphite.
Short description of Pennsylvania deposits (p. 71.)

WALCOTT, C. D.
Pre-Cambrian Fossilliferous Formations.
Bull. Geol. Soc. Amer., Vol. X, p. 227, 1899.
Brief reference to the graphite deposits at Graphite, N. Y. The enclosing rocks are believed to be metamorphosed sediments.

WALKER, JOHN A.

The Manufacture and Use of Lead Pencils.

Graphite Tradesman (Joseph Dixon Crucible Co.,) Aug. 15, 1906.

Description of the process of manufacture of lead pencils.

WATSON, THOMAS L.

Mineral Resources of Virginia, pp. 188-189, 1907.

Brief description of the graphite localities of Virginia.

WEINSCHENK, E.

Memoire sur l'Histoire Geologiqque du Graphite.

Comptes Rendus de la VIII Session, Congress Geologique International. Vol. I, pp. 447-457, Paris, 1901.

From a study of the graphite deposits of Ceylon, and Bavaria as well as some other less important deposits, the author comes to the conclusion that graphite owes its origin to igneous action, the decomposition of hydrocarbons.

Weitere Beobachtungen uber die Bildung des Graphites, speziell mit Bezug auf den Metamorphisms der alpinen Graphitlagerstatten.

Zeit. f. Prakt. Geol. Vol. XI, pp. 1624, 1903.

Emphasizes the effect of igneous action in the production of graphite.

WHITE, DAVID.

Some Problems of the Formation of Coal.

Econ. Geol., Vol. III, p. 298, 1908.

"The discovery of hydrocarbon-bearing strata composed largely of such organisms (algae) in rocks as old as the Ordovican strongly suggests an algal origin for the graphites interbedded in still older metamorphic sediments of the Laurentian or Algonkian."

WINCHELL, ALEXANDER N.

A Theory for the Origin of Graphite as Exemplified in the Graphite Depostis near Dillon, Montana.

Econ. Geol., Vol. VI, pp. 218-230, 1911.

Advances the theory that the graphite of pegmatites and veins has been derived from CO or CO_2.

Graphite near Dillon,, Montana.

U. S. Geol. Survey, Bull. No. 470, pp. 528-532, 1911.

Describes the graphite deposits near Dillon and discusses the origin of vein and pegmatitic graphite.

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